

# THE ASTROPHYSICAL JOURNAL

An International Review of Spectroscopy and  
Astronomical Physics

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# THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND  
ASTRONOMICAL PHYSICS

VOLUME LXXVIII

JULY 1933

NUMBER 1

## THE PHOTOVISUAL MAGNITUDE OF THE COMPANION OF SIRIUS

By A. N. VYSSOTSKY

### ABSTRACT

The photovisual magnitude of Sirius B has been determined anew by two different methods designed to eliminate systematic errors: (1) by using a coarse grating and (2) by forming artificial double stars comparable to Sirius A and B on the photographic plate. The first method gives the magnitude 7.25 and the second gives 6.91, the mean being 7.1 as compared with Wendell's value of 8.44.

### I

In 1930 the author found reason to doubt the usually accepted value of the apparent magnitude of the companion of Sirius.<sup>1</sup> The discrepancy was large enough either to cut the predicted relativity shift in half and to reduce the mean density correspondingly or to raise by several thousand degrees the usually accepted surface temperature. The preliminary value of the photovisual magnitude was 7.1, as compared with the accepted value 8.44 obtained by Wendell with the so-called Rochon prism photometer.<sup>2</sup> The magnitude derived by Wendell has recently been confirmed by the visual observations of Kuiper with the 10-inch refractor of the Leiden Observatory.<sup>3</sup> Since no details of his work have been published, it is difficult

<sup>1</sup> *Publications of the Astronomical Society of the Pacific*, **42**, 155, 1930.

<sup>2</sup> Dr. J. Haas has been kind enough to point out an error which occurred on p. 158 of the writer's paper. Cf. also Aitken, *Binary Stars*, p. 229, 1918.

<sup>3</sup> *Bulletin of the Astronomical Institutes of the Netherlands*, **6**, 197, 1932.

to use the results of Kuiper for any critical comparison with the conclusions herewith presented. However, it is evident that the observations of Wendell with the double-refracting prism photometer, on account of the very great differences in brightness, are very probably affected by systematic errors, physiological, psychological, and instrumental.<sup>4</sup>

Although it seems probable that the magnitude of Sirius B derived by the author<sup>5</sup> in 1930 was not affected by appreciable systematic errors, it is of interest to try different methods which give more complete assurance against possible sources of errors—in particular, errors depending on the properties of a faint photographic image close to a very bright one. Two such methods have been tried, and are described in Sections II and III.

## II

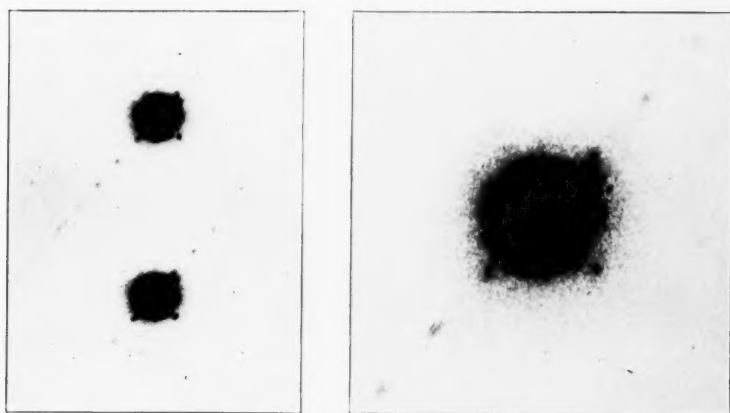
A coarse grating was designed, so that when it was placed over the 26-inch objective of the visual refractor of this observatory, it gave first-order spectra of the same intensity and at the same distance from Sirius A as the image of Sirius B.<sup>6</sup> After constructing several gratings, satisfactory results were obtained with a grating made of spring brass wire, No. 36 B. & S. gauge, spaced at intervals of 12.6 mm. The thickness of the wire, as measured with micrometer calipers, was found to be 0.129 mm. The first-order spectra of Sirius formed by this grating match the images of Sirius B very closely, as far as brightness is concerned, the estimated difference not exceeding 0.2 mag. (see Pl. I). With the spacing of the wires as indicated above, the distance of the first-order spectra from the center of the image of Sirius A is equal to 9".01, while the distance of Sirius B as measured on the same plates was found to be 9".09. Consequently, it may be safely assumed that all photographic effects of the bright central image are identical on both the first-order spectra and Sirius B, especially as the plates show that on account of the high quali-

<sup>4</sup> *Harvard Annals*, 64, 160, 1912.

<sup>5</sup> *Publications of the American Astronomical Society*, 7, 20, 1931.

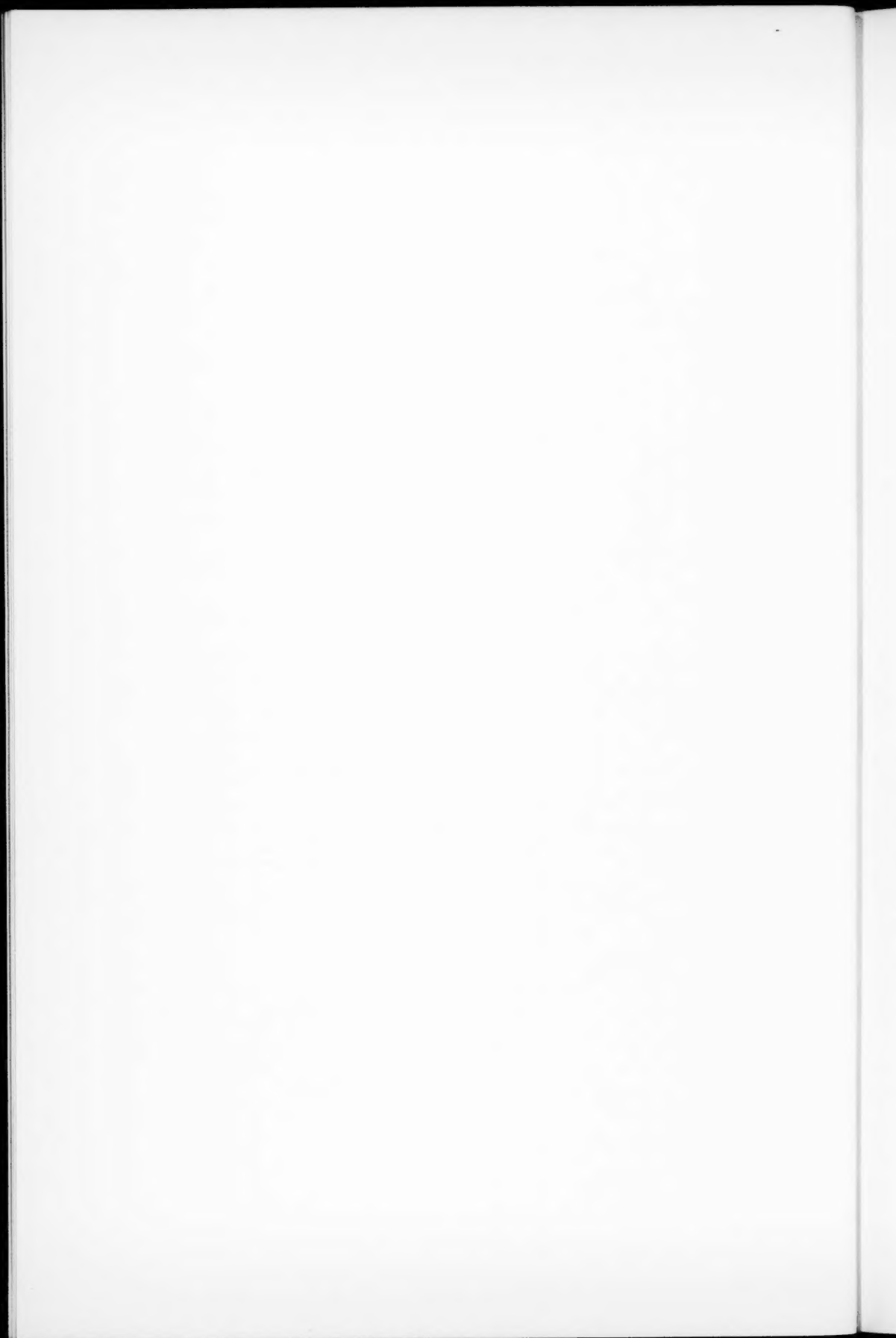
<sup>6</sup> While working on this particular detail of the problem, it became known to me that Dr. van den Bos of the Union Observatory, South Africa, had made some experiments in photographing Sirius B with a similar device. Cf. also Hertzsprung, *Astronomische Nachrichten*, 186, 177, 1910.

PLATE I



SIRIUS A AND B WITH DIFFRACTION SPECTRA OF SIRIUS A  
Enlarged seven and one-half times and twenty times





ties of the 26" objective the pattern of the overexposed image of Sirius A is symmetrical in practically all directions. On the McCormick photographs, the distance  $A-B$  is approximately  $\frac{1}{2}$  mm.

Altogether eighty-two satisfactory images of Sirius B have been obtained on five nights. The exposure times varied from twenty to sixty seconds, the best images being obtained with exposures of thirty seconds. Cramer's Iso Medium plates and Wratten filter No. 12 were used throughout. The same plates and filter have been used for all additional investigations connected with this problem. To prevent halation all plates were backed.

It is a well-known fact that the theoretically computed grating constant often deviates from the value found from observations. In order to derive this value from observations, the following procedure was adopted. Several bright stars were photographed and spectra of the second, third, fourth, and fifth orders were measured with the Schilt microphotometer with respect to known sequences of faint stars. Two bright stars in the Pleiades, Alcyone and Atlas, were thus compared with stars Nos. 193, 220, 238, 239, 278, 279, 280, 314, 332, 374, 378, 381, 388, 392, 393, and 413 of Graff's list;<sup>7</sup>  $\alpha$  Tauri (two plates) and  $\alpha$  Arietis were compared with stars Nos. 25, 28, 36, 37, 40, 43, 49, 58, 59, 64, 110, 129, 140, and 136 of the same list. The reduction of the magnitudes of the fainter Pleiades, as determined by Graff, to the International Scale and zero point was derived by comparing Graff's magnitudes with those of Shapley and Richmond.<sup>8</sup> For the magnitudes of Alcyone,  $\alpha$  Arietis and  $\alpha$  Tauri, King's photovisual magnitudes,<sup>9</sup> corrected by  $+0.07$  for zero point,<sup>10</sup> were adopted. The magnitude of Atlas as observed by Graff was corrected according to Seares.<sup>11</sup> Taking the mean of five determinations, the following values, which show the dependence of the magnitude of the spectral image on the order of the spectrum, are derived:

Order of the spectrum . . . . .	2	3	4	5
(Spectrum—Central image) . . . . .	8.86	9.25	9.40	9.66

<sup>7</sup> *Astr. Abhandl. d. Hamb. Sternwarte in Bergedorf*, 2, 8-19, 1920.

<sup>8</sup> *Mount Wilson Contributions*, No. 218, 1921.

<sup>9</sup> *Harvard Annals*, 85, 181, 1928.

<sup>10</sup> *Mt. Wilson Contr.*, No. 288, pp. 11-12, 1925.

<sup>11</sup> *Ibid.*, p. 14.

These values follow a linear formula satisfactorily; a least-squares solution gives for the reciprocal of the slope of the straight line the value  $0.27 \pm 0.06$  mag., and for the magnitude of the second-order spectrum 8.88 mag. In order to see whether this value may not be affected by a systematic error inherent in the method of measuring with the Schilt photometer, estimates of magnitudes of the second-order spectra of the same stars were made with a low-power magnifying glass with respect to the same set of comparison stars. The mean of the five comparisons was found to be 9.12 mag., which does not differ appreciably from the value 8.88 found above. Taking this last value and the difference, 0.27, between the magnitudes of the successive spectra, we have:

$$(\text{First-order spectrum} - \text{Central image}) = \text{Grating const.} = 8.61 \text{ mag.} \quad (1)$$

It seems hardly likely that the grating constant changed much from night to night since it was found that the images of the spectra of first order never differed from those of Sirius B by more than two-tenths of a magnitude. Nevertheless, an attempt was made to check the derived value of the grating constant by comparing the grating spectra with images of Sirius A reduced with the rotating sector and neutral absorbing filter, thus making the whole comparison in less than an hour. Two openings of the sector (2 and 3 per cent) were used with a neutral film absorbing about 5 mag. The exact amount of the total reduction of light by this device was derived by independent photographic observations of Polaris (with respect to the North Polar Sequence), and of  $\alpha$  Aurigae and  $\alpha$  Tauri (with respect to the Pleiades). The measurements with the Schilt microphotometer gave for the second-order spectra the value 8.82 mag. Using the difference between the first- and second-order spectra, 0.27, derived above, we get:

$$(\text{First-order spectrum} - \text{Central image}) = 8.55 \text{ mag.} \quad (2)$$

Taking the mean of the two values (1) and (2), we get:

$$\text{Grating const.} = 8.58 \text{ mag.}$$

It is interesting to discover the cause of the deviation of the difference in magnitude (Spectrum—Central image) given on page 3 from those predicted by the classical formula according to which each of the first five diffraction images should be 9.96 mag. fainter than the central image. At first it was thought that part of the deviation might be accounted for in a manner suggested by Bucerius,<sup>12</sup> namely, that when the grating is used in connection with a round aperture, the classical formula no longer applies. Accordingly, a square aperture 18 inches on each side was placed in front of the lens, and the magnitudes of the diffraction images were derived again in a manner similar to that outlined above, with the following results:

Order of spectrum.....	2	3	4	5
(Spectrum—Central image).....	8.93	9.13	9.31	9.66

It will be seen that these are practically identical with the values obtained with the round aperture. This indicates that the effect predicted by Bucerius is negligible in the present case. It is possible that reflection of light by the brass wires of the grating may be the chief contributing cause of the observed discrepancy; however, no further investigation along this line was carried out. It is very improbable, on the other hand, that the fogging of the background of the plate, owing to the scattered light of the central image, has any influence on the derived figures, since, according to microphotometer readings, the spectra of the fifth, fourth, and third orders are free from fog, and the spectra of the second order are in a very light fog.

Using the value of the grating constant, 8.58, we can derive the magnitude of Sirius B by assuming some value for the magnitude of Sirius A. The difference between the intensities of images of Sirius B and of first-order spectra of Sirius A was estimated in all cases to be less than the difference between the spectra of first and second orders, which equals 0.27 mag. It has been thought safe to assume the equality of the magnitude of Sirius B to that of the spectrum of first order.

There are two published values of the magnitude of Sirius A. One is the photovisual magnitude derived by King,<sup>13</sup> reduced to the zero

<sup>12</sup> *Astronomische Nachrichten*, 246, 44, 1932.

<sup>13</sup> *Loc. cit.*

point of the international system by adding  $+0.07$  mag.; this is equal to  $-1.33$  mag. This value then gives for the magnitude of the companion of Sirius:

$$-1.33 + 8.58 = 7.25 \text{ mag.} \quad (A)$$

The other is the visual magnitude of Sirius A,  $-1.58$ , derived by Wendell;<sup>14</sup> it gives for the magnitude of Sirius B the value  $7.08$ .

It would seem that a more direct method of comparing the images of Sirius B and of the grating spectra of Sirius A with some standard stars could be used, thus eliminating the uncertainty as to the magnitude of Sirius A. Unfortunately, there are no stars in the field of the 26-inch refractor near Sirius which are bright enough to permit such a comparison. Attempts to use more distant standard sequences, such as Harvard Standard Region D<sub>3</sub>, the Pleiades or Praesepe, were not successful, owing mainly to the rare occurrence of nights with seeing excellent enough to photograph the companion of Sirius, and also owing to somewhat different conditions of guiding at the telescope in very large hour angles.

### III

In the preliminary investigation of the magnitude of the companion of Sirius, mentioned above, the magnitude of Sirius B was derived by comparing its images taken under the rotating sector (8 per cent opening) with the faint stars in the same field. The main objection against the method was that the conditions under which the photographic images of Sirius B had been produced were different from those for the comparison stars. A year later the author showed<sup>15</sup> that the combined action of prefogging and of Eberhard effect is, in this particular case, negligible. More material of the same nature has been collected since. Combining the evidence used previously with the newly obtained information, we have the following results.

Eighteen images of Sirius B reduced with the rotating sector with 8 per cent opening were compared either directly with the stars of the North Polar Sequence or with the set of comparison stars in the

<sup>14</sup> *Op. cit.*, 64, 168, 1912.

<sup>15</sup> *Publications of the American Astronomical Society*, 7, 20, 1931.

field of Sirius. The magnitudes of these comparison stars were derived by means of five independent comparisons with the North Polar Sequence. The resulting magnitude, as reduced by the rotating sector, was found to be 9.68. The amount of reduction, in magnitudes, by the rotating sector was derived in the following manner: (a) seven stars of average magnitude 7.15 were photographed under the rotating sector set at 8 per cent and compared with the North Polar Sequence; (b) nine stars in Praesepe ranging from 6.2 to 9.6 were photographed under the sector and compared with other stars of the same cluster, the magnitudes being taken from the list of van den Bos.<sup>16</sup> The derived value for the sector set at 8 per cent is 2.77, as compared with the theoretical value 2.74. Thus, the observed magnitude of Sirius B comes out equal to

$$9.68 - 2.77 = 6.91. \quad (B)$$

In deriving this value the magnitude of Sirius A does not enter into consideration. On the other hand, there remain possible errors introduced by prefogging, Eberhard effect, etc., owing to the close proximity of the very bright extended image of Sirius A. To determine how large the combined effect of these errors is, four plates were obtained on which a very bright star (Sirius or Altair) was photographed over the densest part of the cluster *h* Persei in order thus to produce, artificially, double-star images similar to the images of Sirius A-B. Nine exposures of the bright star and seven equal exposures of the cluster stars were made on each plate. Altogether sixteen of such double-star images were obtained which were comparable to the images of Sirius A-B. In each case the magnitude of the "faint component" was compared with the magnitude of other images of the same star when it was not playing the rôle of faint component. No appreciable difference in magnitude was found in any of the sixteen comparisons, the density of the image of the faint component being always small, as in the case of Sirius B; parenthetically, with considerably denser faint components, the well-known influence of the Eberhard effect was plainly observed on the same plates. It would seem, then, that the simultaneous action of

<sup>16</sup> *Bulletin of the Astronomical Institutes of the Netherlands*, 1, 79, 1922.

prefogging and the Eberhard effect may be safely neglected in the case of Sirius B.

#### IV

It is difficult to decide which value, (*A*) or (*B*), should be given higher weight. Taking the straight mean of the two values, we have for the final value of the apparent photovisual magnitude of the companion of Sirius:

$$m_{pv} = 7.1.$$

It seems fairly safe to conclude that the probable error of the derived magnitude does not exceed 0.2 mag.

The absolute photovisual magnitude, using the value of the parallax  $0''.368$ ,<sup>17</sup> is then equal to +9.9 mag. As was pointed out in my previous paper, this indicates either that the density of the companion of Sirius is about one-sixth of the value usually assumed or that the surface temperature is fully 50 per cent higher than the temperature corresponding to the spectral class A7. It would be of great importance to investigate the magnitude of Sirius B in several colors, especially in the ultra-violet, as has been pointed out to me by Miss C. H. Payne. Equally urgent is an investigation of the energy distribution in the spectrum of the white dwarf companion of  $\sigma^2$  Eridani, which should not present any special difficulty.<sup>18</sup>

My thanks are due to Mr. C. A. Wirtanen of this observatory, who greatly assisted in constructing the various gratings used in the present investigation, and also to Professor C. M. Sparrow for a valuable discussion concerning the characteristics of coarse gratings.

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UNIVERSITY OF VIRGINIA

February 1933

<sup>17</sup> *Publications of the Astronomical Society of the Pacific*, **42**, 156, 1930.

<sup>18</sup> Lindblad, *Mt. Wilson Contr.*, No. 228, 1922; Öhman, *Monthly Notices of the Royal Astronomical Society*, **92**, 71, 1931; Williams, *Publications of the Astronomical Society of the Pacific*, **45**, 45, 1933.

## TEMPERATURE CLASSIFICATION OF THE SPECTRUM OF NEODYMIUM<sup>1</sup>

By ARTHUR S. KING

### ABSTRACT

The paper gives the temperature classification of 2863 neodymium lines in the spectral range  $\lambda\lambda$  2963–7005, based on their relative intensities at three temperature stages of the electric furnace. The neutral spectrum, strong in the furnace, includes many lines that are faint in the arc, especially in the shorter wave-length region, a large proportion of which are now measured for the first time. The spectrum is notable for the large number of lines in classes I and II, which are well developed at 2000° C, while the neutral lines in higher classes appear near 2300°. The classification includes also the stronger lines of singly ionized neodymium, selected by comparing the furnace spectra with those of the arc and spark. A majority of these enhanced lines are present in the furnace spectrum at 2600°. Wave-lengths of 2026 lines were measured, comprising new neutral lines and others for which improved wave-lengths could be obtained. The dominance of the lines of *Nd* I, *Nd* II, and *Nd* III in different spectral ranges is discussed.

A comparison of neodymium spectrograms with those of samarium was made with reference to lines apparently common to both spectra, which might belong to the intermediate element 61. Lines of this character given by the samples used in this investigation appear, however, to result from chance coincidences of true neodymium and samarium lines.

The spectrum of neodymium, produced at different temperatures of the electric furnace and in the arc and spark, presents features similar to those discussed in the writer's previous papers<sup>2</sup> on rare-earth spectra. We find, as before, a close resemblance between the arc and spark spectra, especially in the short wave-length region, and the appearance of a multitude of lines in the furnace spectrum which are very faint in the arc. These features are explained by the predominance of enhanced lines in the arc spectrum, while the furnace is highly effective in bringing out the spectrum of the neutral atom. Like those of other rare earths of even atomic number, neodymium lines, when examined under moderate resolving power, do not show hyperfine structure.

*Experimental method.*—Following the usual procedure, the spectrograms were made in the second order of the 15-foot concave grat-

<sup>1</sup> Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington, No. 470.

<sup>2</sup> *Mt. Wilson Contr.*, No. 368, *Astrophysical Journal*, **68**, 194, 1928; *Mt. Wilson Contr.*, No. 414, *Astrophysical Journal*, **72**, 221, 1930; *Mt. Wilson Contr.*, No. 439, *Astrophysical Journal*, **74**, 328, 1931.

ing (scale, 1 mm = 1.86 Å) as far as  $\lambda$  5400, while the first order was used for the orange and red regions. Spectrograms for the furnace, charged with neodymium chloride, were made at temperatures of approximately 2600°, 2300°, and 2000° C. On account of the prolonged exposures required for full registration of the low-temperature spectrum in the second order, check plates were made throughout the spectrum in the first order. Spectrograms of the spark, as well as of the arc, were made in each region for the segregation of enhanced lines, and the identification of these lines was confirmed by a mixture of neodymium with caesium in the furnace. The higher electron pressure resulting from the low ionization potential of caesium permits increased recombination in the neodymium vapor and a consequent weakening of the enhanced lines.

Other supplementary spectrograms were made in order to supply reference spectra of high purity and to facilitate wave-length measurements when these were required. The neodymium chloride used in most of the work contained enough praseodymium and samarium to give the stronger lines of these elements. A small amount of very pure neodymium oxide, prepared by G. Urbain, of Paris, was used for furnace and arc spectrograms to confirm the selection of the lines included in the table. Spectrograms for wave-length measurements of furnace lines were made at moderate temperature with a mixture of iron to supply the reference lines, while, for wave-lengths of arc lines, adjacent spectra of neodymium and iron arcs were photographed by means of an occulting device. Another occulting arrangement was used to photograph the arc spectra of very pure neodymium and samarium samples with the spectrum of the iron arc between. This permitted the measurement, from the same iron standards, of neodymium and samarium lines of nearly coincident wave-lengths.

*Explanation of the table.*—The spectrum of neodymium is very rich in lines. Of the great number appearing in the arc which are shown by the present study to belong to the ionized atom, only the stronger are included in Table I. The neutral lines, which with the more persistent enhanced lines make up the furnace spectrum, are listed with a greater degree of completeness, especially when they

appear at low temperature. Very faint neutral lines appearing only at high temperature are omitted, as in some cases these may be unidentified impurity lines or possibly lines belonging to the carbon band structure.

The wave-lengths in Table I are from several sources. Of the 2863 lines listed, the wave-lengths of 2026 were measured by the writer, with the assistance of Miss Brayton, and are entered without superscript in the first column. A large proportion of these are neutral lines measured on the furnace spectrograms, and in many cases, by reason of their faintness in the arc, have not been recorded by previous observers. Other wave-lengths by the writer are revisions of existing values, especially for enhanced lines when these appeared very sharp in the furnace and could be measured from iron standards. Still other measures are for the components of close doublets, previously recorded as single lines. A considerable number of near coincidences of neutral and ionized lines were detected by a close comparison of adjacent arc and furnace spectra. Measurements relative to the same standards in the two spectra gave appreciable wave-length differences.

Wave-lengths other than those measured in the present investigation are indicated by superscripts in the first column of Table I, as follows:

1. Bertram [converted to I.A.]<sup>3</sup>
2. Exner and Haschek [converted to I.A.]<sup>4</sup>
3. Kiess<sup>5</sup>

An asterisk (\*) after a wave-length refers to a note at the end of the table; "d" indicates an unresolved doublet.

The intensities in Table I are for the arc and high-temperature furnace only, those estimated for the medium and low temperatures being omitted to save space. The magnitudes of the latter may be inferred from the classes in the final column. Thus the outstanding lines at low temperature, showing little relative increase at higher temperatures, are placed in class I, while other low-temperature

<sup>3</sup> *Zeitschrift für wissenschaftliche Photographie*, **4**, 16, 1906.

<sup>4</sup> *Spektren der Elemente*, **2**, 1911.

<sup>5</sup> *Scientific Papers of the Bureau of Standards*, **18**, 201 (No. 442), 1922.

lines which strengthen with higher excitation go into class II. Lines of class III appear first at medium temperature and strengthen rapidly. Classes IV and V require, respectively, the highest furnace temperature or appear only in the arc. A large proportion of the stronger enhanced lines, denoted by "E" after their class numbers, are listed in the last three classes.

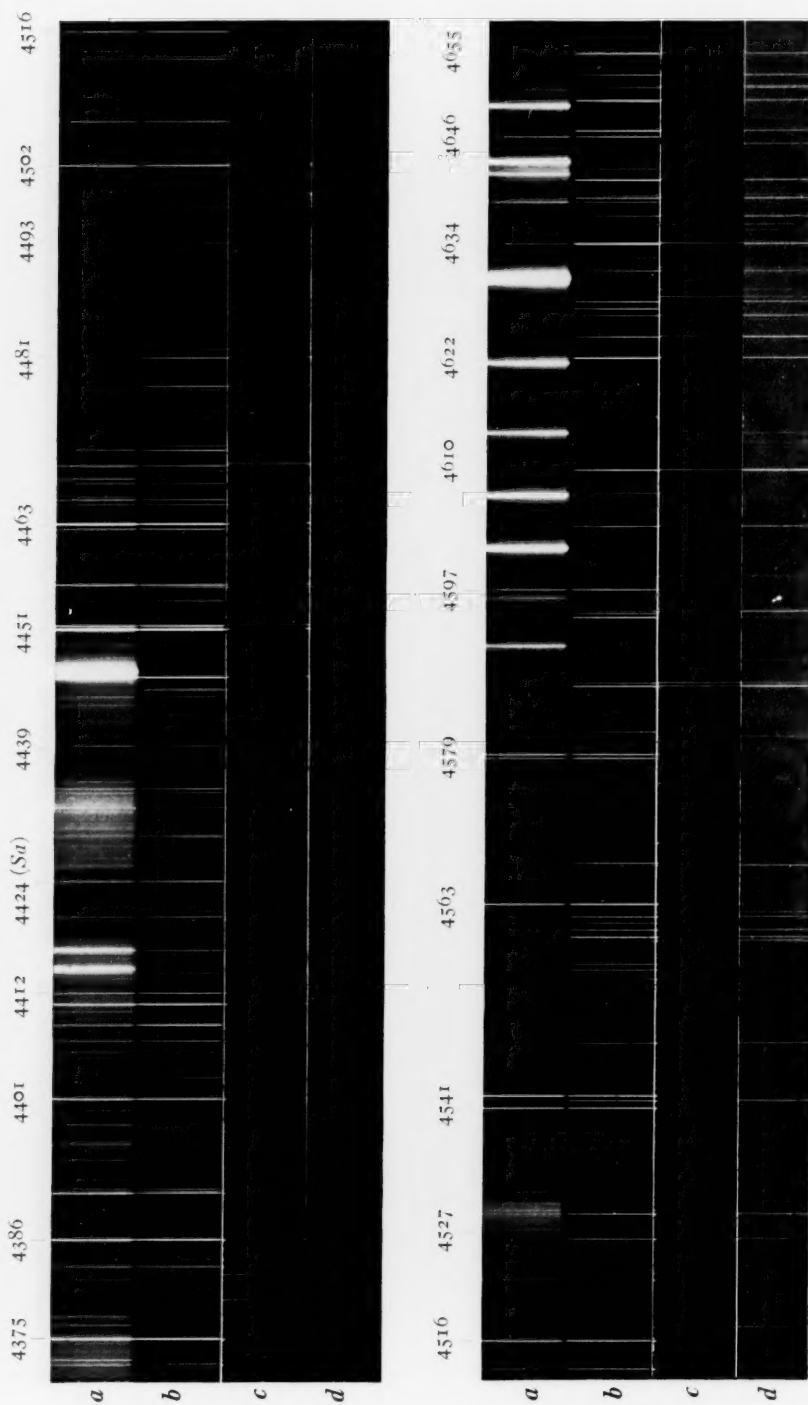
Neutral lines which are relatively much stronger in the furnace than in the arc have "A" after their class numbers. The large number of lines so designated is due chiefly to the inherent faintness in the arc of many lines which are given distinctly by the furnace, but in part to the difficulty of estimating the intensities of these lines and the strong enhanced lines from the same arc spectrograms. An exposure to the arc sufficient to give intensities of several units to the faint neutral lines results in such overexposure of the enhanced lines that estimation is impossible. Arc spectra were selected which were favorable for the estimation of relative differences among the stronger lines. On these plates many of the neutral lines are in the threshold range of intensity, indicated by "1—" in the arc column.

*Features of the neodymium spectrum.*—Comparison of spectrograms of the spark, arc, and furnace shows that the first part of Table I, to about  $\lambda$  3400, includes three spectra of neodymium. The lines of doubly ionized neodymium, previously recognized by the writer<sup>6</sup> but not yet measured, dominate this portion of the spark spectrum and extend to still shorter wave-lengths. Singly ionized lines are becoming numerous in arc and spark, and some of the stronger lines are entered in the table; but the singly ionized spectrum has by no means the richness which it attains at wave-lengths greater than  $\lambda$  3600. The furnace has great difficulty in producing emission lines of such short wave-length, but some appear at the highest temperature. As no lines appear at medium temperature below  $\lambda$  3313, those of shorter wave-length necessarily go into class IV, although they are doubtless the low-level lines of this region. At wave-lengths greater than  $\lambda$  3300, neutral lines are numerous in the furnace spectrum, though faint in the arc, and prominent low-temperature lines of classes I and II begin to appear near  $\lambda$  3500.

<sup>6</sup> *Physical Review*, **31**, 309, 1928.



# PLATE II



## SPECTRUM OF NEODYMIUM

- a*) Spark spectrum
- b*) Arc spectrum
- c*) Furnace spectrum, 2400° C.
- d*) Furnace spectrum, 2000° C.

A few high-temperature lines are probably masked by the cyanogen bands with heads at  $\lambda$  3590 and  $\lambda$  3883, but the low-temperature lines in this stretch were obtained on plates from which the bands were absent. Some high-temperature spectrograms for the violet and blue gave enough continuous ground to show the low-temperature lines in absorption and aided in the selection of lines in classes I and II. Between  $\lambda$  3700 and  $\lambda$  4500, the strength in the arc and persistence in the furnace of many ionized lines are notable features, the lines of class III E forming a group of low-level lines of Nd II.

Beginning at  $\lambda$  4400, some neutral lines have sufficient strength in the arc to be included in the previous tables of arc wave-lengths. A large proportion of these lines are strong at low temperature and appear self-reversed in the high-temperature furnace. From this point on through the red, neutral lines dominate the arc spectrum, but many enhanced lines occur as well, some with high intensities. In the red, we find a number of lines which have exceptional strength in the furnace as compared with the arc. These as a rule are now measured for the first time; but the present evidence gives no reason to doubt that they belong to neodymium.

Plate II gives a comparison of spark, arc, and furnace spectra in the range  $\lambda\lambda$  4400–4600. The enhanced lines (of about equal strength in arc and spark) are conspicuous, and strong neutral lines appear in this region. The temperature of the upper furnace spectrum was not so high as that often used, but still sufficient to give the stronger enhanced lines. This spectrum includes many lines of the high-temperature group, while the low-temperature spectrum shows the lines of classes I and II.

In general, the neutral lines of sufficient intensity in either furnace or arc to be included in Table I appear to arise from two groups of closely associated levels. Lines in the lower group are distinct at 2000° C and go for the most part into class I, the less persistent being placed in class II. The balance of the neutral lines listed appear near 2300° and behave usually as class III lines. Higher temperatures, up to 2800°, are effective mainly in strengthening the enhanced lines, to which group, except in the ultra-violet, nearly all the lines in classes IV and V belong.

TABLE I  
TEMPERATURE CLASSIFICATION OF NEODYMIUM LINES

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
2962.885 <sup>1</sup> ...	20	.....	VE	3130.489....	1	1	IV
2963.579 <sup>1</sup> ...	40	.....	VE	3133.602 <sup>1</sup> ...	100	.....	VE
2993.20 <sup>2</sup> ....	50	.....	VE	3133.887....	1	2	IV A
2999.944....	1	2	IV A	3134.895 <sup>1</sup> ...	50	.....	VE
3007.97 <sup>2</sup> ....	50	.....	VE	3135.471d....	1	2	IV
3014.191 <sup>1</sup> ...	60	.....	VE	3136.679....	3	3	IV
3014.701 <sup>1</sup> ...	8	.....	VE	3137.070....	1	2	IV A
3018.353 <sup>1</sup> ...	40	.....	VE	3137.245 <sup>1</sup> ...	30	.....	VE
3036.987....	1	2	IV A	3140.552....	1	2	IV A
3038.979 <sup>1</sup> ...	6	.....	VE	3141.404 <sup>1</sup> ...	40	.....	VE
3050.467....	1	1	IV	3142.44 <sup>2</sup> ....	30	.....	VE
3051.112 <sup>1</sup> ...	8	.....	VE	3143.303....	2	2	IV
3051.667....	1	1	IV	3144.552 <sup>1</sup> ...	20	.....	VE
3052.148 <sup>1</sup> ...	15	.....	VE	3144.824 <sup>1</sup> ...	40	.....	VE
3056.712 <sup>1</sup> ...	40	.....	VE	3145.125....	2	2	IV
3065.688....	1	1	IV	3146.011....	3	4	IV
3069.727 <sup>1</sup> ...	15	.....	VE	3148.511 <sup>1</sup> ...	20	.....	VE
3071.430....	6	.....	VE	3148.941....	1	2	IV A
3071.495....	6	.....	VE	3149.286 <sup>1</sup> ...	40	.....	VE
3075.380 <sup>1</sup> d...	50	.....	VE	3149.511 <sup>1</sup> ...	40	.....	VE
3079.378 <sup>1</sup> ...	40	.....	VE	3151.010....	2	2	IV
3080.111 <sup>1</sup> ...	15	.....	VE	3153.210 <sup>*</sup> ...	?	5	IV
3080.940 <sup>1</sup> ...	30	.....	VE	3154.370....	1	1	IV
3080.961 <sup>*</sup> ...	?	2	IV	3155.706....	3	3	IV
3085.234....	1	1	IV	3155.763 <sup>1</sup> ...	10	.....	VE
3089.173....	3	5	IV	3156.259....	4	5	IV
3089.677....	5	5	IV	3158.261 <sup>*</sup> ...	3 <sup>?</sup>	3	IV
3092.616 <sup>*</sup> ...	?	2	IV	3159.203 <sup>1</sup> ...	10	.....	VE
3092.867 <sup>*</sup> ...	?	2	IV	3160.542....	1	1	IV
3092.924 <sup>1</sup> ...	60	.....	VE	3162.009 <sup>*</sup> ...	2 <sup>?</sup>	4	IV A
3093.898....	3	3	IV	3162.624 <sup>1</sup> ...	40	1	IV E
3094.207....	1	2	IV A	3164.563....	2	2	IV
3096.831....	2	3	IV	3166.247....	4	4	IV
3098.482 <sup>1</sup> ...	50	1	VE	3168.299....	1	2	IV A
3099.522 <sup>1</sup> ...	8	.....	VE	3170.016....	5	5	IV
3105.426 <sup>1</sup> ...	30	.....	VE	3175.105....	1	2	IV A
3106.177 <sup>1</sup> ...	20	.....	VE	3175.988 <sup>1</sup> ...	30	.....	VE
3108.014 <sup>1</sup> ...	30	.....	VE	3178.925 <sup>1</sup> ...	10	.....	VE
3113.230....	3	3	IV	3179.300 <sup>*</sup> ...	3 <sup>?</sup>	3	IV
3114.860....	2	3	IV	3180.215....	2	2	IV
3115.181 <sup>1</sup> ...	100	.....	VE	3181.54 <sup>2</sup> ....	10	.....	VE
3116.149 <sup>1</sup> ...	60	.....	VE	3182.356....	1	2	IV A
3119.753 <sup>1</sup> ...	15	.....	VE	3183.272....	5	5	IV
3122.510....	2	3	IV	3188.73 <sup>2</sup> ....	15	1	IV E
3123.065 <sup>1</sup> ...	20	.....	VE	3190.710....	3	4	IV
3124.082 <sup>1</sup> ...	12	.....	VE	3191.098....	5	3	IV
3124.576 <sup>1</sup> ...	40	.....	VE	3191.857....	5	6	IV
3127.179....	2	3	IV	3193.078 <sup>1</sup> ...	10	.....	VE
3129.802....	1	2	IV A	3194.427....	5	5	IV

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
3197.677....	3	4	IV	3266.735....	1	2	IV A
3200.622 <sup>1</sup> ....	10	.....	VE	3267.248 <sup>1</sup> ....	30	1	IVE
3203.468 <sup>1</sup> ....	30	2	IV E	3272.225....	2	4	IV A
3205.914....	4	4	IV	3272.830....	4	2	IV
3207.671....	2	3	IV	3273.181 <sup>1</sup> ....	15	1	IVE
3208.500....	2	2	IV	3274.456....	3	5	IV
3210.306....	1	2	IV A	3275.220 <sup>1</sup> ....	60	2	IVE
3210.907 <sup>1</sup> ....	8	.....	VE	3275.830 <sup>1</sup> ....	15	.....	VE
3213.286....	3	4	IV	3276.128 <sup>1</sup> ....	10	.....	VE
3215.280*....	?	2	IV	3279.927....	1	2	IV A
3216.153....	2	3	IV	3280.212....	3	2	IV
3216.506....	1	2	IV A	3281.171....	2	2	IV
3217.123 <sup>1</sup> ....	25	.....	VE	3282.267....	1	3	IV
3217.540....	3	3	IV	3282.832....	8	.....	VE
3220.535....	2	2	IV	3285.006 <sup>1</sup> ....	50	3	IVE
3222.176....	2	3	IV	3286.621 <sup>1</sup> ....	20	1	IVE
3222.525 <sup>1</sup> ....	10	.....	VE	3288.581....	3	4	IV
3223.773*d....	6	6	IV	3290.651 <sup>1</sup> ....	25	2	IVE
3226.961....	1	2	IV A	3291.497....	1	2	IV A
3228.044 <sup>1</sup> ....	20	.....	VE	3292.706....	1	4	IV A
3228.154*....	?	3	IV	3293.231....	1	2	IV A
3228.362....	1	2	IV A	3293.838 <sup>1</sup> ....	10	.....	VE
3228.829....	1	2	IV A	3294.092....	1	3	IV A
3231.247....	1	2	IV A	3294.680 <sup>1</sup> ....	15	1	IVE
3231.346*....	?	2	IV	3300.161 <sup>1</sup> ....	70	4	IVE
3231.664*....	?	2	IV	3300.356....	1	2	IV A
3232.510....	1	2	IV A	3300.511....	1	2	IV A
3236.490....	3	4	IV	3300.914 <sup>1</sup> ....	20	1	IVE
3237.424....	1	2	IV A	3301.420....	1	3	IV A
3237.914 <sup>1</sup> ....	20	.....	VE	3302.020....	1	3	IV A
3238.253 <sup>1</sup> ....	10	.....	VE	3302.859....	1	2	IV A
3238.469d....	2	4	IV A	3304.610....	1	2	IV A
3239.290....	1	3	IV A	3304.657 <sup>1</sup> ....	10	.....	VE
3241.713....	4	5	IV	3306.380....	15	4	IVE
3242.453....	2	6	IV A	3307.199....	1	2	IV A
3245.708....	2	2	IV	3309.756....	2	2	IV
3249.780*....	?	2	IV	3310.379 <sup>1</sup> ....	15	1	IVE
3249.975....	2	2	IV	3310.911 <sup>1</sup> ....	30	2	IVE
3250.978....	6	5	IV	3312.753....	25	2	IVE
3251.802....	6	5	IV	3313.158 <sup>1</sup> ....	20	1	IVE
3254.082 <sup>1</sup> ....	15	3	IVE	3313.646....	3	5	III
3254.986*....	?	4	IV	3313.909....	1	3	IV A
3255.617....	2	3	IV	3314.050....	2	3	IV
3256.914 <sup>1</sup> ....	15	.....	VE	3314.575....	1	1	IV
3259.244 <sup>1</sup> ....	30	3	IVE	3316.015 <sup>1</sup> ....	20	1	IVE
3260.663 <sup>1</sup> ....	20	2	IVE	3316.123....	2	4	III A
3262.524....	3	4	IV	3316.911d....	3	5	III
3265.125 <sup>1</sup> ....	30	.....	VE	3317.272....	1	1	IV
3265.376 <sup>1</sup> ....	20	.....	VE	3317.515....	1	2	IV A
3265.559....	1	3	IV A	3318.415 <sup>1</sup> ....	10	1	IVE

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
3320.004....	1	3	IV A	3379.642....	1	2	IV A
3320.421*....	2	3	IV	3382.004....	1	3	IV A
3321.400....	3	5	III	3382.090....	10	4	IV A
3322.341....	2	4	III A	3383.449....	3	6	III A
3325.732....	8	8	II	3385.640....	1	4	III A
3325.901 <sup>1</sup> ....	30	3	IV E	3386.517 <sup>1</sup> ....	20	1	IV E
3328.044 <sup>1</sup> ....	10	1	IV E	3387.073....	2	4	IV A
3328.276....	80	4	IV E	3387.953....	3	5	II
3328.552....	1	1	IV	3388.030 <sup>1</sup> ....	15	.....	VE
3328.986....	3	4	III	3389.035....	1	2	IV A
3329.695....	1	2	IV A	3391.635....	1	3	IV A
3330.806....	4	4	III	3391.944....	2	6	II A
3331.574 <sup>1</sup> ....	40	2	IV E	3393.634....	60	3	IV E
3332.587....	2	4	III A	3396.160....	3	3	IV
3333.058....	6	6	II	3397.441....	3	6	II A
3334.480 <sup>1</sup> ....	50	3	IV E	3399.818....	1	3	III A
3335.777....	1	2	IV A	3400.901....	1	3	III A
3337.454....	1	2	IV A	3403.687....	1	3	III A
3339.067....	60	3	IV E	3405.681....	2	3	IV
3339.747....	6	6	II	3408.019....	2	6	II A
3346.539....	2	4	III A	3409.676....	3	5	II
3346.589....	6	4	II	3410.246 <sup>1</sup> ....	40	2	IV E
3346.700....	2	3	III	3411.018....	15	3	IV E
3347.559 <sup>1</sup> ....	10	1	IV E	3413.660....	1	3	III A
3348.169....	25	2	IV E	3416.730....	1	3	III A
3348.597....	4	6	III	3420.878....	1	3	IV A
3349.637....	2	3	IV	3422.363....	1	3	IV A
3351.172....	2	3	IV	3424.072....	2	4	III A
3353.521....	4	5	III	3425.210 <sup>1</sup> ....	30	1	IV E
3353.587 <sup>1</sup> ....	20	1	IV E	3428.931 <sup>1</sup> ....	40	2	IV E
3354.059....	6	6	II	3430.423....	1	2	IV A
3354.534....	1	3	III A	3434.066....	1	3	III A
3354.603 <sup>1</sup> *....	10	2	IV E	3434.424....	1	4	III A
3355.927....	40	2	IV E	3438.480....	1	3	III A
3356.317....	2	4	III A	3440.266....	1	5	III A
3358.514....	8	8	II	3442.680....	1	4	III A
3359.762 <sup>1</sup> ....	15	1	IV E	3443.321 <sup>1</sup> ....	20	1	IV E
3361.895....	1	4	III A	3443.604 <sup>1</sup> ....	15	1	IV E
3362.261*....	10 <sup>2</sup>	6	III	3445.897....	4	8	III A
3364.958....	50	3	IV E	3447.624 <sup>1</sup> ....	8	2	IV E
3365.704....	1	2	IV A	3449.539....	1	4	III A
3367.411....	2	3	IV	3449.632....	1	4	III A
3368.716....	1	2	IV A	3451.278....	1	2	IV A
3368.874....	3	2	IV	3451.735....	1	3	III A
3369.263*....	4	2	IV	3454.382....	10	3	IV E
3372.924....	1	1	IV	3455.403....	1	3	III A
3373.093....	4	8	II A	3455.753*....	4	5	III
3375.227....	15	2	IV E	3456.001*....	6	2	IV E
3375.466....	1	2	IV A	3456.779....	1	8	III A
3376.918....	3	3	IV	3458.012 <sup>1</sup> ....	10	.....	VE

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
3458.957 <sup>1</sup> ...	15	1	IV E	3500.665....	2	2	IV
3450.031....	1	5	III A	3501.215....	1	3	IV A
3461.662....	1	3	III A	3501.845....	1	5	IV A
3461.722....	1	4	III A	3503.237....	1—	3	III A
3462.801....	1	3	III A	3504.211....	1	5	III A
3463.604....	1	4	III A	3505.823....	2	3	IV
3464.405*	?	5	III	3506.020....	6	12	II A
3468.410....	20	3	IV E	3506.550....	1	6	III A
3468.559....	1	2	III A	3506.723....	3	6	III A
3470.310....	1	3	III A	3507.991....	1	2	IV A
3470.865....	20	3	IV E	3508.860....	1	4	III A
3471.097....	1	5	III A	3509.234....	1	4	III A
3472.253....	1	3	IV A	3510.701 <sup>1</sup> ...	20	1	IV E
3472.372*	?	3	III A	3511.412....	1	3	III A
3473.215....	2	2	IV	3512.052....	1	2	III A
3474.663....	2	2	IV	3512.736*	?	5	III A
3474.805....	1	3	III A	3512.900....	1—	3	IV A
3475.100 <sup>1</sup> ...	12	1	IV E	3513.660....	1	5	IV A
3476.370....	3	5	III	3515.173....	1	3	III A
3477.255....	3	5	III	3515.298....	1	2	IV A
3477.806....	3	5	III	3516.018....	1	4	III A
3478.039....	1	3	III A	3516.203....	1	2	III A
3479.289....	1—	3	III A	3516.899....	1	5	IV A
3479.572....	2	3	III	3517.839....	1	2	III A
3480.562....	3	6	III A	3518.428....	1	6	III A
3481.436 <sup>1</sup> ...	20	2	IV E	3522.046 <sup>1</sup> ...	25	1	IV E
3482.751....	1	2	III A	3522.090....	4	6	III
3483.113....	1	5	III A	3523.950....	1	2	III A
3483.803....	1	5	III A	3525.394....	1—	1	IV A
3484.360*	8	3	IV E	3527.532 <sup>1</sup> ...	35	1	IV E
3484.875....	4	3	III	3529.059....	2	4	III A
3485.377....	1	5	III A	3531.708*	10	1	IV E
3485.569....	2	4	III A	3532.886....	1	4	III A
3487.331....	1	2	III A	3533.588 <sup>1</sup> ...	30	1	IV E
3488.054....	2	3	III	3534.176....	1	2	III A
3489.293....	4	6	III	3537.620....	2	4	II A
3490.024....	1	2	III A	3541.605 <sup>1</sup> ...	20	1	IV E
3490.797....	2	6	II A	3543.353....	50	3	IV E
3491.366....	4	6	III A	3543.470....	2	3	III
3491.483....	2	1	IV	3549.257....	1	2	III A
3492.792....	1	3	III A	3550.897....	1	2	III A
3493.597....	2	3	III	3555.774 <sup>1</sup> ...	25	1	IV E
3494.952....	1	2	III A	3560.749 <sup>1</sup> ...	40	2	IV E
3495.711....	2	4	III A	3561.611 <sup>1</sup> ...	15	1	IV E
3496.519....	3	6	III A	3562.460....	1	4	II A
3496.876....	1	2	III A	3563.590....	1	2	III A
3498.214....	1	3	III A	3564.106....	1—	4	III A
3498.281....	3	4	III	3566.336....	5	5	III
3499.530....	1	3	III A	3566.553....	6	6	III
3500.079....	1	2	IV A	3567.006....	1	2	III A

TABLE I—Continued

λ	INTENSITY		CLASS	λ	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
3568.869....	40	2	IV E	3633.647....	1	3	III A
3569.489....	2	6	III A	3634.305 <sup>1</sup> ....	40	2	IV E
3570.403....	4	10	II A	3634.873 <sup>1</sup> ....	15	2	III E
3581.505....	1	5	III A	3636.733....	1	3	III A
3582.319....	2	4	III A	3637.002 <sup>1</sup> ....	25	.....	VE
3582.402....	1	4	III A	3637.232 <sup>1</sup> ....	30	.....	VE
3582.885*....	?	5	III A	3637.791 <sup>1</sup> ....	20	.....	VE
3583.214....	2	5	III A	3640.235*....	30	.....	VE
3583.887....	1—	3	III A	3640.520....	1	6	II A
3584.944....	2	3	III	3641.500 <sup>1</sup> ....	25	2	III E
3585.353*....	?	1	III	3642.205....	3	8	III A
3585.602....	4	6	I	3643.627....	10	2	IV E
3586.167....	1	3	III A	3645.770....	15	5	IV E
3587.507....	50	4	IV E	3648.158 }	15	{ 5 2	II
3588.309....	1—	3	III A	3648.196 }			VE
3589.175....	1—	6	III A	3648.344....	1	2	III A
3590.802....	1	2	III A	3650.422 <sup>1</sup> ....	15	2	IV E
3592.090*....	?	4	III A	3653.150 <sup>1</sup> ....	15	.....	VE
3592.589....	60	5	IV E	3655.031 <sup>1</sup> ....	10	1	IV E
3593.527d....	4	3	III	3657.987....	3	6	II A
3595.271....	1—	6	III A	3658.108*....	2	10	II A
3596.002....	1—	6	III A	3658.668....	1	3	III A
3596.820....	1	4	III A	3659.123....	1	5	III A
3597.519....	1	3	III A	3659.264....	1	4	III A
3598.024....	20	4	IV E	3659.945....	10	4	III E
3598.639....	1	5	III A	3661.347....	10	2	IV E
3600.014....	25	2	IV E	3662.263 <sup>1</sup> ....	30	2	IV E
3602.554....	2	4	II A	3664.649*....	3	10	II A
3604.868d....	2	5	III A	3665.179....	50	6	IV E
3605.509....	12	4	III A	3665.755*....	5	6	III
3605.709....	3	4	III	3666.408....	1	3	III A
3606.921....	1—	3	III A	3666.566....	1	3	III A
3607.012....	1—	2	III A	3667.564*....	1	5	II A
3609.788....	40	5	III E	3669.101....	1	4	III A
3610.218....	1	3	II A	3670.017....	1	5	II A
3610.946....	2	2	III	3670.916....	6	4	III
3611.711....	1	4	III A	3671.337....	1—	3	III A
3615.815....	30	3	IV E	3672.363 <sup>1</sup> ....	50	1	VE
3617.223....	1—	3	III A	3673.434*....	?	6	II
3618.963....	30	3	IV E	3673.542 <sup>1</sup> ....	50	1	VE
3619.423....	1—	3	III A	3674.056*....	5	8	IV
3621.300....	1	3	III A	3675.295....	1	5	II A
3622.843....	1	4	III A	3676.753....	1	5	III A
3624.319....	4	4	III A	3678.184....	15	2	IV E
3624.485....	1—	2	III A	3678.655....	1	3	III A
3624.654....	15	2	IV E	3679.215....	1	3	IV A
3628.445....	2	10	I A	3679.404....	2	5	III A
3629.940....	10	.....	VE	3681.858....	3	5	II
3631.02 <sup>2</sup> ....	20	.....	VE	3682.336....	1	3	III A
3632.201....	1	3	III A	3683.042....	4	8	II A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
3684.131*	6	8	III	3732.298....	1	8	IA
3685.804 <sup>†</sup> ...	60	3	IV E	3732.785....	10	.....	VE
3687.213....	1	4	II A	3733.058....	3	10	II A
3687.206....	40	3	IV E	3733.838....	1	5	IA
3689.602....	30	3	IV E	3735.227....	1	3	III A
3690.080*	1	4	II A	3735.537....	20	4	IV E
3691.357....	1	4	II A	3735.599 <sup>†</sup> ...	10	.....	VE
3692.781....	1—	4	III A	3738.056....	40	4	IV E
3693.557....	1	6	III A	3738.744....	1	2	III A
3694.807 <sup>†</sup> ...	10	.....	VE	3740.240....	1	4	III A
3695.686....	1	3	III A	3741.424....	50	5	III E
3697.565 <sup>†</sup> ...	10	1	IV E	3742.153....	2	3	II
3699.404....	2	5	III A	3744.809d....	4	8	III A
3699.766*	3	4	III A	3745.466....	3	8	IA
3700.514 <sup>†</sup> ...	10	2	IV E	3746.128....	2	3	II
3701.485....	2	8	III A	3747.803....	1—	3	III A
3701.982....	4	6	III	3748.674....	1	3	II A
3703.328....	1	3	II A	3749.853*	?	3	II
3703.803....	1—	3	III A	3750.947....	1	5	IA
3707.164....	4	5	III	3752.287....	2	3	III
3707.740....	2	6	II A	3752.376....	1—	3	III A
3710.417....	1	3	II A	3752.492....	40	4	IV E
3711.545....	2	4	II A	3752.674....	30	5	IV E
3712.128*	5	6	III	3754.353....	2	4	III A
3713.607....	25	1	VE	3755.595....	30	4	IV E
3714.196....	15	.....	VE	3756.004....	2	8	III A
3714.236*	?	10	III A	3756.580....	2	5	IA
3714.602*	?	4	II	3757.819....	30	3	IV E
3714.733....	12	.....	VE	3757.944*	3	6	III A
3714.811....	20	5	IV E	3758.947 <sup>†</sup> ...	40	4	III E
3715.044....	15	.....	VE	3759.702 <sup>†</sup> ...	20	2	IV E
3715.394....	15	.....	VE	3761.075....	1—	3	III A
3715.678....	20	4	IV E	3761.242....	1—	3	III A
3716.679....	10	1	IV E	3762.210....	1—	6	IVA
3717.482....	2	5	III A	3763.474....	60	6	III E
3719.595....	1	5	III A	3765.344*	?	5	III A
3720.276....	1—	5	II A	3769.654 <sup>†</sup> ...	40	4	III E
3720.892....	1	3	III A	3769.818....	1	4	II A
3721.017....	1	4	II A	3772.055....	15	3	IV E
3721.350 <sup>†</sup> ...	20	.....	VE	3772.138....	1—	6	II A
3721.486....	1—	4	III A	3772.402....	10	8	III
3721.687....	3	6	IA	3773.338....	6	6	I
3722.323....	1	4	III A	3774.780....	1	4	IA
3723.505....	50	6	III E	3775.497 <sup>†</sup> ...	20	2	IV E
3723.804....	1—	5	III A	3775.740....	1	4	IA
3724.874....	30	5	III E	3777.815....	1	6	IA
3726.007....	1	3	III A	3778.826....	3	4	III
3728.128....	50	5	III E	3779.467....	40	6	IV E
3730.577....	30	4	IV E	3779.761d....	4	10	II A
3731.221....	20	3	IV E	3780.308 <sup>†</sup> ...	20	2	IV E

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
3780.919....	2	5	II A	3830.468 <sup>1</sup> *...	20	.....	VE
3781.318 <sup>1</sup> ...	20	2	IV E	3830.915....	3	10	IA
3781.776....	3	5	I	3831.030....	2	15	IA
3783.060*....	4	8	III A	3832.178....	1	4	III A
3784.250....	80	8	III E	3834.404....	2	15	IA
3784.847....	20	2	IV E	3836.104....	2	0	II A
3785.106*....	?	4	I	3836.542*....	60	?	IV E
3785.992....	2	6	II A	3837.909 <sup>1</sup> ...	20	2	IV E
3787.521....	6	6	I	3838.970....	80	5	III E
3790.653....	2	3	III	3839.507 <sup>1</sup> ...	15	1	IV E
3791.243....	1	3	III A	3840.775....	1	5	IA
3791.373....	1	3	III A	3842.695....	4	4	I
3791.595....	20	.....	VE	3848.235....	50	5	IV E
3792.304....	2	4	IA	3848.309....	40	4	IV E
3793.640....	4	4	I	3848.523....	80	0	IV E
3794.686....	2	5	IA	3850.225 <sup>1</sup> ...	20	1	IV E
3795.452 <sup>1</sup> ...	20	3	III E	3851.657....	30	3	IV E
3796.037....	4	3	I	3851.745....	60	0	IV E
3801.384*....	2?	8	II A	3862.516 <sup>1</sup> ...	15	.....	VE
3801.922....	2	8	II A	3862.828....	1—	2	II A
3803.474 <sup>1</sup> ...	40	4	III E	3863.326*....	20	?	IV E
3805.128....	1—	4	III A	3863.404*....	60	?	IV E
3805.356....	100	12	III E	3864.550....	1	3	III A
3805.546....	20	4	III E	3864.806....	3	3	II A
3805.784....	1—	3	III A	3865.980 <sup>1</sup> ...	10	?	IV E
3806.102....	1—	4	III A	3866.517 <sup>1</sup> ...	15	?	IV E
3806.230....	1	5	II A	3866.806 <sup>1</sup> ...	10	?	IV E
3806.540....	1	5	IA	3869.070 <sup>1</sup> ...	30	3	IV E
3807.539....	2	4	IA	3875.735....	20	2	IV E
3807.942*....	?	4	III	3875.807....	40	4	IV E
3808.774....	30	4	III E	3876.229....	1	3	III A
3809.058 <sup>1</sup> ...	25	4	IV E	3876.722....	2	4	IA
3810.491 <sup>1</sup> ...	40	3	IV E	3878.582....	50	4	IV E
3811.063 <sup>1</sup> ...	20	2	IV E	3879.546....	40	?	IV E
3811.772 <sup>1</sup> ...	20	3	IV E	3880.375....	30	?	IV E
3812.852....	2	15	II A	3880.778....	40	4	IV E
3814.730....	60	5	III E	3884.962....	1	5	II A
3815.599....	1	2	III A	3886.088....	4	0	II
3817.385....	15	6	III E	3886.917....	1—	2	III A
3817.846....	1	3	III A	3887.837*....	?	6	II A
3820.866....	4	10?	IA	3887.87*....	30	0	III E
3821.132....	2	4	IA	3888.712....	1—	2	III A
3821.383....	1—	3	III A	3889.003....	1	6	IV A
3822.474d....	20	2	IV E	3889.214....	1	4	II A
3826.422....	60	5	III E	3889.66d....	20	2	IV E
3827.995....	30	4	IV E	3889.93....	50	5	IV E
3828.366....	1	3	IA	3890.138....	1—	3	III A
3828.848 <sup>1</sup> ...	40	2	IV E	3890.22....	8	1	IV E
3829.156 <sup>1</sup> d..	30	2	IV E	3890.58....	50	5	IV E
3830.000....	2	3	IA	3890.94....	60	5	III E

## THE SPECTRUM OF NEODYMIUM

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TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
3891.51.....	20	2	IV E	3934.82 <sup>2</sup> ....	50	6	IV E
3891.720.....	1—	3	III A	3935.917....	4	4	I
3892.06*d....	10	1—	V E	3936.11 <sup>2</sup> ....	15	1	V E
3893.408.....	1—	3	III A	3937.00 <sup>2</sup> *....	1—	4	IV A
3893.665.....	1—	2	IV A	3937.57 <sup>2</sup> *....	5	5	IV E
3894.63.....	40	4	III E	3938.545.....	1—	3	III A
3895.37.....	3	.....	V E	3938.86 <sup>2</sup> ....	40	2	IV E
3896.13.....	10	5	IV E	3939.52 <sup>2</sup> ....	8	1	IV E
3897.337.....	1—	4	IV A	3939.844.....	2	5	III A
3897.63.....	12	4	IV E	3940.320....	1	2	IV A
3898.323.....	1—	3	III A	3941.513.....	150	6	III E
3898.687.....	1—	3	II A	3941.572*....	?	1	IV
3900.214.....	60	8	III E	3942.12 <sup>2</sup> *....	4	1	IV E
3900.531.....	1	4	III A	3942.62 <sup>2</sup> ....	6	2	IV E
3901.376.....	1—	4	III A	3944.422....	5	4	I
3901.84.....	50	5	IV E	3947.607....	5	15	II A
3902.511.....	1—	5	II A	3948.147....	4	6	I
3904.067.....	1	2	III A	3948.32 <sup>2</sup> ....	15	3	IV E
3905.106.....	1—	4	III A	3949.458....	2	6	III A
3905.888.....	100	10	III E	3951.156....	150	10	III E
3906.09.....	10	4	IV E	3952.196....	100	6	III E
3907.84.....	20	3	IV E	3952.869....	25	5	IV E
3909.151.....	1	3	III A	3953.400*....	10	2	IV E
3910.708.....	1	2	III A	3953.524....	60	5	IV E
3911.16.....	60	5	IV E	3954.214....	1	6	II A
3912.23.....	20	2	IV E	3955.95 <sup>2</sup> ....	10	3	IV E
3913.955.....	?	6	II A	3956.796....	3	4	III
3913.546.....	3	5	I	3957.042....	1	6	III A
3913.69.....	8	2	IV E	3957.45 <sup>2</sup> ....	15	1	IV E
3914.938.....	2	4	II A	3958.00 <sup>2</sup> ....	40	6	III E
3915.13.....	8	1	IV E	3958.627....	1—	2	III A
3915.194.....	1—	3	II A	3962.21 <sup>2</sup> ....	4	2	IV E
3915.95.....	20	4	IV E	3963.116....	15	6	IV E
3919.92.....	10	2	IV E	3963.180*....	60	8	IV E
3920.96.....	100	8	III E	3963.90 <sup>2</sup> ....	?	3	III A
3923.122.....	2	6	III A	3964.19 <sup>2</sup> ....	20	4	IV E
3924.083.....	1—	4	III A	3964.29.....	5	1	IV E
3924.250.....	1—	4	III A	3964.29.....	2	4	IV A
3924.405.....	1—	4	II A	3967.06 <sup>2</sup> ....	15	4	IV E
3924.49.....	8	3	IV E	3967.75 <sup>2</sup> ....	10	2	IV E
3924.727.....	1	8	IV A	3967.812....	2	4	III A
3925.495*....	?	4	IV A	3970.263....	1—	2	III A
3925.936.....	1—	6	III A	3971.318....	1—	2	III A
3926.615*....	?	3	III A	3972.753....	1	6	II A
3927.10.....	40	5	IV E	3973.30 <sup>2</sup> ....	80	8	IV E
3928.449.....	1—	8	II A	3973.69 <sup>2</sup> ....	60	6	III E
3929.26.....	15	3	IV E	3973.912....	1—	6	III A
3932.931.....	1—	12	II A	3974.489....	1—	4	III A
3934.090*....	6 {	.....	V E	3976.091....	1—	6	III A
3934.107*....			IV	3976.630....	1—	8	III A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
3976.85 <sup>2*</sup> ...	60	5	III E	4021.876....	5	5	II A
3979.40 <sup>2</sup> ....	60	5	III E	4023.03 <sup>2</sup> ....	80	8	IV E
3981.24 <sup>2</sup> ....	15	4	IV E	4024.78 <sup>2</sup> ....	30	4	IV E
3981.689....	4	4	I	4030.47 <sup>2</sup> ....	25	5	IV E
3982.269....	4	4	I	4031.524 <sup>1</sup> ....	10	3	IV E
3982.36 <sup>2</sup> ....	20	4	IV E	4031.82 <sup>2</sup> ....	100	8	IV E
3983.41 <sup>2</sup> ....	10	2	IV E	4032.506....	6	20	II A
3985.782....	1—	3	III A	4032.725....	1	10	II A
3986.25 <sup>2</sup> ....	40	2	IV E	4033.331....	1—	2	III A
3986.957....	1—	4	III A	4035.168....	1—	4	II A
3987.434 <sup>*</sup> ....	3	3	III	4036.01....	4	.....	VE
3987.81 <sup>2</sup> ....	5	3	IV E	4037.37 <sup>2</sup> ....	2	4	IV A
3988.82 <sup>2</sup> ....	8	2	IV E	4037.043....	5	15	II A
3989.591....	1—	2	IV A	4038.12 <sup>2</sup> ....	20	4	IV E
3990.017 <sup>*</sup> ....	?	4	II	4039.061....	1—	3	II A
3990.100....	60	6	IV E	4040.799....	100	10	III E
3991.745....	80	8	III E	4041.06 <sup>2</sup> ....	15	4	IV E
3992.60 <sup>2</sup> ....	15	1	IV E	4041.513....	1—	1	III A
3992.981d....	6	20	II A	4042.589....	2	20	II A
3994.452....	2	4	I A	4043.594 <sup>1</sup> ....	15	4	IV E
3994.72 <sup>2</sup> ....	80	8	III E	4044.347 <sup>1</sup> ....	5	1	IV E
3995.26 <sup>2</sup> ....	15	3	IV E	4047.159....	4	12	III A
3996.036....	1—	5	II A	4048.806 <sup>1</sup> ....	15	1	IV E
3997.135....	2	12	III A	4051.15 <sup>2</sup> ....	60	5	IV E
3997.44 <sup>2</sup> ....	10	1	IV E	4051.623....	1	4	II A
3997.684....	1	4	II A	4053.519....	2	4	I A
3999.090....	1	8	II A	4054.554....	1—	8	III A
4000.497....	30	4	IV E	4054.718....	1—	12	III A
4000.554....	20	3	IV E	4054.86 <sup>2</sup> ....	10	2	IV E
4002.123....	1—	4	III A	4055.345....	1	4	III A
4004.015....	60	6	III E	4056.83 <sup>2</sup> ....	4	.....	VE
4004.136....	1	4	II A	4056.893....	1	1	IV
4007.43 <sup>2</sup> ....	50	4	IV E	4057.134....	1—	1	III A
4007.82....	1—	4	IV A	4057.37 <sup>2</sup> ....	1—	2	III A
4007.964 <sup>*</sup> ....	1—	6	II A	4057.762....	1	6	III A
4009.377....	4	15	I A	4058.232....	1	5	II A
4010.45 <sup>2</sup> ....	10	2	IV E	4059.06....	50	4	IV E
4010.757....	2	4	I A	4060.504....	3	6	IV A
4011.09 <sup>2</sup> ....	15	3	IV E	4061.092....	200	10	III E
4011.462....	1	4	III A	4062.897 <sup>*</sup> ....	?	5	I A
4012.251....	300	20	III E	4065.991....	1—	5	IV A
4012.703....	50	6	III E	4066.185....	1	6	II A
4013.25 <sup>2</sup> ....	15	4	IV E	4066.860....	2	15	I A
4017.173....	1—	5	III A	4067.729 <sup>*</sup> ....	4	2	III
4018.81 <sup>2</sup> ....	30	5	IV E	4067.926....	1—	4	III A
4019.79 <sup>2</sup> ....	12	1	IV E	4068.804....	10	3	IV E
4020.05 <sup>2</sup> ....	5	1—	IV E	4069.277....	80	10	III E
4020.87 <sup>2</sup> ....	60	6	III E	4071.252....	1	2	III A
4021.34 <sup>2</sup> ....	80	5	III E	4071.455 <sup>*</sup> ....	?	2	III A
4021.78 <sup>2</sup> ....	60	6	III E	4073.618....	1	12	III A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4074.420	8	2	IV E	4109.162*	1?	10	IA
4075.119	60	6	IV E	4109.458	200	20	III E
4075.275	50	6	IV E	4110.483	40	5	III E
4078.008	1—	5	II A	4110.552	1—	5	II A
4078.360	1—	2	III A	4110.692	1—	5	III A
4080.058	1	10	III A	4112.742	1	4	III A
4080.232	50	5	IV E	4113.831	20	5	IV E
4081.650	1	5	II A	4113.960	1—	2	III A
4082.547	3	—	VE	4114.458	3	20	III A
4083.916	6	5	I	4115.070	1—	12	II A
4084.263	3	5	II	4116.771	30	6	IV E
4084.638	1—	1	IV A	4118.19	1	8	III A
4084.963	1—	2	III A	4118.821	1	4	II A
4085.824	30	5	IV E	4120.656	6	1	IV E
4086.17	1—	4	III A	4121.938	4	—	VE
4086.920	1—	2	III A	4122.098*	4	10	IA
4087.478	4	1	IV E	4123.884	40	5	IV E
4087.804	1—	2	III A	4124.10	1—	5	IV A
4088.560	6	1	IV E	4125.048*	5	6	I
4088.790	2	5	II A	4125.809	1—	4	II A
4088.870	1	5	II A	4126.059	1—	5	II A
4089.122	4	1	IV E	4126.563	1	12	II A
4089.680	4	—	VE	4127.626	1—	2	III A
4091.001	3	—	VE	4128.120	3	—	VE
4092.427	1—	5	III A	4128.705	2	—	VE
4092.658	2	12	II A	4129.873	3	6	III A
4094.617	5	1	IV E	4130.724	3	—	VE
4095.428	4	—	VE	4132.555	10	1	IV E
4095.782	3	—	VE	4133.358	50	6	IV E
4096.131	30	4	IV E	4134.715	10	1	IV E
4096.714	4	1	IV E	4135.331	10	1	IV E
4098.178	20	3	IV E	4135.790	3	1	IV E
4098.52	2	8	III A	4135.933	2	15	III A
4098.912	3	—	VE	4136.233	2	—	VE
4099.412	1	10	II A	4136.755	10	2	IV E
4100.003	1—	4	III A	4137.988	2	10	III A
4100.243	15	4	IV E	4139.796	1—	6	III A
4101.454	4	—	VE	4140.587	2	10	II A
4101.684	3	—	VE	4142.022	1	6	II A
4102.53	4	—	VE	4143.04*	1?	6	IV A
4103.015	1	10	III A	4144.562	20	3	IV E
4104.230	10	2	IV E	4145.198	1—	4	IV A
4104.545	4	—	VE	4146.130	10	1	IV E
4105.880*	1—	6	II A	4148.586	1—	3	III A
4106.580	8	2	IV E	4149.331	1—	3	III A
4106.724	1	2	III A	4149.863	1—	3	III A
4107.445	4	1—	IV E	4151.108	1—	4	III A
4107.744	2	2	III	4151.350	1	12	III A
4107.962	4	—	VE	4151.678	10	1—	VE
4109.082	100	10	III E				

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4153.347	1—	5	III A	4203.600	1	8	III A
4153.604	1—	5	III A	4205.254*	10	?	IV E
4153.734	4	.....	VE	4205.271*	1—	8	III A
4154.129	1—	2	III A	4205.603d	40	5	IV E
4155.141	1—	1	III A	4205.78*	1—	4	IV A
4156.085	250	20	III E	4207.244	1	5	II A
4156.257	30	6	IV E	4208.16	1—	4	IV A
4156.857	1—	5	III A	4210.988	3	15	I A
4157.581	3	.....	VE	4211.292	40	4	IV E
4159.568	4	.....	VE	4212.45	1—	8	III A
4160.568	30	4	IV E	4212.751	6	1	IV E
4160.642	1—	8	II A	4213.066	4	.....	VE
4160.84	1—	4	IV A	4213.145	1—	10	III A
4164.854	5	8	IV	4213.215	5	.....	VE
4165.041	5	.....	VE	4214.225*	4	2	IV E
4165.319	1	5	II A	4214.605	12	3	IV E
4168.760	3	.....	VE	4217.281	5	1	IV E
4170.461	4	.....	VE	4218.548	3	.....	VE
4170.758 <sup>d</sup>	6	.....	VE	4219.530	1—	6	III A
4171.012	1	4	II A	4219.564	4	.....	VE
4173.375	8	2	IV E	4220.253	20	5	IV E
4173.610	1—	6	II A	4221.038	1—	5	IV A
4174.847	1—	2	III A	4221.137*	5	?	II A?
4174.914	1	10	III A	4221.181	1—	4	III A
4175.610	50	5	IV E	4223.208	5	1	IV E
4176.100	1	4	II A	4224.360	2	6	II A
4177.322	200	10	III E	4224.842	8	1	IV E
4178.438*	6	.....	VE	4226.002	4	1—	IV E
4178.534	8	1	IV E	4227.570	1	5	II A
4178.643	15	3	IV E	4227.720	30	4	IV E
4179.588	30	4	IV E	4228.027	10	3	IV E
4182.290	2	.....	VE	4228.201	8	2	IV E
4182.517	4	1	IV E	4228.533 <sup>1</sup>	2	.....	VE
4183.134	2	8	II A	4228.833	2	.....	VE
4184.079	15	1	IV E	4229.50 <sup>1</sup>	5	2	IV E
4186.036	8	3	IV E?	4229.86	1—	3	III A
4186.311	1	6	II A	4232.380	150	8	III E
4192.419	1—	2	III A	4234.094	1—	6	II A
4195.026	30	4	IV E	4234.194	6	.....	VE
4196.565	1	5	IV A	4235.237	6	1	IV E
4196.668	1	8	II A	4239.159	1	2	III A
4196.839	1	3	III A	4239.837	10	1	IV E
4197.507	1—	6	III A	4241.034	1—	4	III A
4198.173	2	.....	VE	4241.211	4	.....	VE
4199.109	10	2	IV E	4242.798	1—	6	II A
4200.039	3	.....	VE	4244.760	1—	2	III A
4200.243	1—	3	III A	4244.964	3	1	IV E
4201.505	1—	2	III A	4245.734	1	4	I A
4202.558	1	3	III A	4245.814	1—	4	I A
4203.428	2	.....	VE	4246.781	2	12	III A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4247.375	200	12	III E	4297.795	3	1	IV ?
4250.210	2	10	II A		30	4	IV E
4250.673	1	10	II A	4299.317	1	2	III A
4252.444	40	2	IV E	4299.706	10	3	IV E
4252.98	1	12	III A	4301.215	4	6	II
4253.873	3	.....	VE	4302.397	1	6	II A
4256.240	8	2	IV E	4303.578	400	25	III E
4256.474	8	30r	I A	4304.452	20	1	VE
4256.825*	8	10	IV E	4305.481 <sup>1</sup>	2	.....	VE
4256.857*			III A	4305.810*	4 <sup>2</sup>	20	II A
4257.787	4	.....	VE	4306.750	4	.....	VE
4257.92	1—	5	IV A	4307.780	15	2	IV E
4258.106	3	6	I A	4308.432	1—	5	III A
4259.618	4	1	IV E	4310.506	6	.....	VE
4261.04	1—	3	III A	4311.254	10	20	I A
4261.714	1—	5	III A	4313.358	2	.....	VE
4261.841	20	1	IV E	4314.376	8	1	IV E
4262.242d	4	.....	VE	4314.515	50	8	III E
4262.458	1	10	II A	4315.864	1—	5	III A
4263.341	1—	4	III A	4319.97	1	8	IV A
4263.440	10	1	IV E	4321.300	1	6	III A
4265.304	1	8	I A	4322.657	1—	2	III A
4265.662	1	12	III A	4323.904	2	.....	VE
4266.142	1—	4	III A	4324.166	1	5	III A
4266.713	30	4	IV E	4325.765*	150	10	IV E
4269.200	1—	3	III A	4327.570	1	5	III A
4270.565	25	5	IV E	4327.933	30	4	IV E
4271.636	1—	5	III A	4328.157	3	8	III A
4272.790	30	5	IV E	4329.917	1—	5	II A
4273.577	1—	1	III A	4331.181	1	6	II A
4273.960	1	3	III A	4337.231	1—	6	II A
4274.077	1	2	III A	4337.596	1—	5	III A
4275.088	10	1	IV E	4338.698	80	8	IV E
4275.179	1	6	II A	4339.98	1—	3	III A
4277.287	6	2	IV E	4340.28	1—	3	III A
4279.294	1—	6	III A	4342.069	20	4	IV E
4281.194	1—	5	III A	4342.536	1—	5	III A
4282.069	1—	6	III A	4343.497	10	20	I A
4282.444	50	5	IV E	4343.970	1—	5	III A
4282.570	15	3	IV E	4347.212	4	8	I A
4282.70	1	10	III A	4348.889	1—	6	III A
4284.303	1—	10	III A	4349.839	1—	5	III A
4284.515	100	8	IV E	4350.206	2	.....	VE
4287.10	1—	8	IV A	4350.51	1—	4	III A
4287.42	1—	8	IV A	4350.73d*	1	10	III A
4290.549	1—	8	III A	4351.21	15	1	IV E
4290.958	6	.....	VE	4351.29	40	4	III E
4291.474	2	4	I A	4354.19	1—	6	IV A
4291.736	1—	10	III A	4355.351	2	.....	VE
4297.356	8	2	IV E	4355.489	2	8	II A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4355.75.....	1—	8	IV A	4397.320....	2	6	II A
4356.021....	10	1?	VE	4397.674 <sup>2</sup> ...	3	1	IV E
4357.573....	2	6	I A	4398.30.....	1—	4	IV A
4357.780....	1—	5	III A	4400.604....	1	4	I A
4358.168....	200	15	III E	4400.830....	100	6	III E
4358.609*...	15	2	IV E	4401.063....	1—	5	III A
4359.240....	5	1	IV E	4402.200....	1	4	III A
4359.71.....	1—	6	IV A	4402.478....	4	8	I A
4359.808....	1	10	III A	4403.707....	1—	4	III A
4360.870 <sup>1</sup> ...	2	.....	VE	4404.01.....	1—	5	III A
4362.685....	1—	4	III A	4404.622....	1	5	II A
4364.140....	10	4	IV E	4404.803....	1—	4	III A
4364.622....	1—	6	III A	4407.075....	10	4	IV E
4366.316....	12	4	IV E	4408.371....	1	8	I A
4366.383....	8	3	IV E	4408.470....	1—	5	III A
4367.62.....	1—	4	IV A	4409.227....	1—	5	III A
4368.637....	60	6	III E	4409.914....	1	6	III A
4370.747....	1	5	II A	4410.250....	2	.....	VE
4371.618....	1	5	II A	4411.064....	150	8	III E
4372.137....	3	.....	VE	4412.200....	20	6	IV E
4372.275....	8	3	IV E	4412.515....	1	2	III A
4372.731....	4	.....	VE	4413.338....	2	.....	VE
4373.138....	1—	5	III A	4414.440....	8	2	IV E
4373.661....	2	6	II A	4414.710....	1—	4	III A
4374.928*...	20	4	IV E	4416.888....	15	2	IV E
4375.041....	30	5	IV E	4417.392....	1	10	I A
4375.457....	1	8	III A	4418.05 <sup>2</sup> ...	1	.....	VE
4376.448....	3	.....	VE	4418.131....	1	6	II A
4377.019....	1	8	II A	4419.623....	1	4	II A
4377.101....	5	.....	VE	4420.110....	1	8	II A
4377.26.....	1—	3	IV A	4422.436....	1	10	II A
4377.399....	4	.....	VE	4423.175....	1	6	II A
4378.82.....	1—	4	IV A	4426.500....	1—	5	IV A
4379.111....	2	6	III A	4426.826....	4	1	IV E
4379.874*...	?	6	II A	4428.096....	4	20	II A
4381.878....	3	5	II A	4432.220....	4	8	I A
4381.934....	2	5	II A	4432.207....	4	.....	VE
4382.730....	15	2	IV E	4433.25....	1—	6	III A
4385.664....	150	10	III E	4434.15....	1—	6	III A
4390.280....	1—	3	III A	4436.14....	1—	6	IV A
4390.661....	20	1	VE	4437.222....	1—	6	III A
4391.104....	10	2	IV E	4438.07....	1	4	IV A
4391.525....	1	4	III A	4439.003....	10	4	IV E
4392.220....	1—	4	III A	4439.954d...	5	30	III A
4393.352....	3	6	II A	4440.48....	1—	4	IV A
4394.182....	2	.....	VE	4442.49....	1	10	III A
4394.717....	1—	4	III A	4443.407....	2	.....	VE
4396.370....	1—	5	III A	4444.287....	6	1	IV E
4396.952....	1—	4	III A	4444.988....	15	50r	I A
4397.188....	1—	3	IV A	4446.387....	200	10	III E

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4448.001....	4	1	IV E	4490.02....	1	8	III A
4448.491....	1—	5	III A	4491.635....	3	.....	VE
4448.895....	1	4	II A	4491.951....	1—	4	II A
4450.688....	1	8	III A	4492.476....	3	.....	VE
4450.96....	1—	4	III A	4492.80....	1—	8	IV A
4451.474....	?	2	III	4493.423....	8	1	IV E
4451.566....	400	10	III E	4494.768....	1	6	IV A
4451.876....	1—	4	III A	4495.105....	2	4	II A
4451.987....	50	4	IV E	4495.409*	1—	5	III A
4452.018*	?	20R	II A	4496.409*	?	4	III A
4453.041....	1—	3	III A	4497.272....	5	1	IV E
4454.091....	1—	6	III A	4497.379....	6	20R	IA
4456.132....	15	20R	I	4497.927....	8	2	IV E
4456.405....	40	4	IV E	4498.521....	1	6	III A
4460.63....	1—	6	IV A	4498.743....	2	10	IA
4462.418....	30	4	IV E	4499.286....	2	4	IA
4462.988....	250	10	IV E	4499.66d....	1	10	IV A
4465.072....	10	3	IV E	4500.112....	1—	8	III A
4465.603....	10	3	IV E	4500.533....	1—	3	III A
4466.145....	1	4	II A	4501.202....	1	6	III A
4466.575....	1—	2	IV A	4501.82....	50	5	IV E
4467.853....	3	.....	VE	4501.952....	2	4	IA
4469.265....	8	1	IV E	4502.444....	1	10	III A
4469.362....	1	6	II A	4504.31....	1—	3	III A
4469.442....	1—	6	II A	4505.011....	1—	4	III A
4469.571....	1	8	II A	4505.587....	2	3	IV
4470.434....	1	4	II A	4506.587....	30	5	IV E
4470.587....	1	6	IV A	4509.443....	2	5	II A
4470.685....	2	4	II A	4509.821....	2	4	II A
4470.970....	6	1	IV E	4510.614....	1—	6	IV A
4471.414....	10	4	IV E	4510.832....	1—	3	III A
4475.574*	5	8	IV	4512.204....	2	4	II A
4475.836....	5	20R	IA	4513.342....	20	4	IV E
4476.518....	1—	4	III A	4514.400....	1—	2	III A
4477.456....	6	1	IV E	4514.884....	1	6	III A
4477.870....	30	50R	I	4516.356*	1	?	IV E
4479.358....	1	5	II A	4516.381*	30	12	III A
4480.072....	25	60R	IA	4516.647....	4	1	IV E
4481.262....	1—	3	III A	4517.796....	2	10	IA
4481.57....	1—	8	IV A	4519.47....	1—	3	IV A
4481.898....	20	30R	I	4522.835....	4	1	IV E
4482.38....	1—	8	III A	4523.582....	4	1	IV E
4483.281....	1	2	III A	4524.848....	1—	10	III A
4483.081....	1—	2	III A	4525.17d....	1	10	III A
4484.178d....	1	1	III	4527.178....	1—	4	III A
4485.950....	3	1	IV E	4527.252....	20	30R	I
4487.12....	1—	4	IV A	4528.422....	1—	4	III A
4487.25....	1—	3	IV A	4529.164....	2	10	IV A
4487.621 <sup>1</sup>	2	.....	VE	4529.765....	2	4	IA
4490.778....	2	.....	VE	4529.944....	40	40R	I

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4530.336	4	.....	VE	4570.069	1	10	IV A
4530.905	1	8	III A	4570.396	1—	10	III A
4531.143	1—	3	III A	4570.820	1—	3	III A
4531.423	1—	8	III A	4571.893	1—	4	IV A
4532.899	1	10	IV A	4576.156	1	8	III A
4534.723	1—	5	IV A	4577.181	1	10	III A
4535.003	1—	2	III A	4578.263	1	6	IV A
4535.950	1—	6	IV A	4578.891	30	3	IV E
4536.204	1—	3	III A	4579.163	1—	4	III A
4536.601	1—	4	III A	4579.315	30	2	IV E
4537.634	2	10	III A	4579.678	1—	3	III A
4539.432	1	8	II A	4581.201	3	5	II A
4541.09	1—	5	IV A	4582.770	1—	10	IV A
4541.272	50	8	III E	4583.538	1	8	III A
4542.055	20	30R	I	4584.038	4	1	IV E
4542.606	60	3	IV E	4586.186	1	6	IV A
4543.306	1	12	III A	4586.396	1—	4	IV A
4543.592	1—	2	III A	4586.617	50	50R	I
4544.250	2	.....	VE	4586.963	8	20	II A
4545.327	2	.....	VE	4588.244	1	6	IV A
4548.244	20	20R	I	4588.921	1	6	IV A
4549.015	3	1—	IV E	4591.472	1	5	IV A
4549.42	1—	5	IV A	4593.950	2	4	III A
4549.938	1—	5	III A	4594.452	6	2	IV E
4550.395	1	12	III A	4594.676	3	20R	IA
4550.741	1—	2	III A	4594.88	1	10	IV A
4551.01	1—	6	III A	4595.12	1—	4	IV A
4552.275	2	.....	VE	4597.020	20	4	IV E
4552.323	1—	4	II A	4597.988	1—	4	III A
4554.146	1	15	IA	4598.427	3	15	II A
4555.142	4	1	IV E	4599.340	2	10	III A
4556.143	12	4	IV E	4600.520	2	.....	VE
4556.740	12	3	IV E	4600.771	1—	2	III A
4557.768	2	6	III A	4601.342	1—	2	III A
4559.189	5	20R?	IA	4602.120	1	4	III A
4559.347	3	20R?	IA	4602.236	2	.....	VE
4559.564	1—	3	III A	4603.819	25	20	I
4559.672	40	40R	I	4604.44	1	4	IV A
4560.423	20	20R	I	4606.761	1—	5	III A
4561.180	8	2	IV E	4607.378*	6	8	IV E
4561.855	20	20R	I	4607.71	1—	4	IV A
4562.346	2	8	IA	4609.22*	?	6	IV A
4563.224	40	4	IV E	4609.811	3	10	IA
4564.746	1—	8	III A	4609.872	15	20R	I
4566.062	1—	8	III A	4611.744	1	10	III A
4567.352	6	10	IA	4612.468	4	1?	IV E
4567.613	12	3	IV E	4612.796d	1	15	II A
4568.03	1	6	IV A	4612.975	1	8	IV A
4569.609*	3	30	II A	4613.361	1—	3	III A
4569.852	2	.....	VE	4613.841	3	4	II A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4617.724....	1—	8	IV A	4651.572....	2	15	III A
4618.061d....	3	15	III A	4652.300....	15	30r	I A
4621.040....	80	80R	I	4652.678....	1	3	III A
4622.205....	1	6	IV A	4653.112....	1—	3	III A
4622.434....	1	6	IV A	4654.204....	3	20	III A
4624.210....	10	20r	I A	4654.726....	60	50R	I
4624.91....	1	4	IV A	4655.575....	1—	4	IV A
4626.034....	1—	5	II A	4656.560....	1—	4	II A
4626.38....	1—	5	IV A	4657.217....	2	8	III A
4626.498....	10	20r	I A	4657.901....	1	5	II A
4626.819....	1—	4	IV A	4658.038....	1—	5	III A
4627.77....	1—	3	IV A	4659.379....	4	15	III A
4627.979....	20	30r	I	4660.470....	1	10	III A
4628.418....	3	15	III A	4661.478....	1—	2	III A
4628.501....	3	10	III A	4662.497....	1	8	III A
4629.253....	4	10	II A	4662.968....	2	.....	VE
4629.908....	4	.....	VE	4663.089....	1	4	IV A
4630.31....	1—	3	IV A	4663.994....	2	5	II A
4631.056....	1—	3	III A	4664.368....	2	8	II A
4631.294....	12	10?	I	4664.450....	4	.....	VE
4631.606....	4	20	III A	4664.613....	1	4	II A
4631.99....	1—	3	IV A	4665.214....	1	8	III A
4632.64 <sup>2</sup> ....	4	.....	VE	4665.532....	1	6	IV A
4634.236....	200	200R	I	4665.904....	1—	5	IV A
4636.297....	5	12	II A	4667.958....	1—	5	IV A
4636.582....	2	.....	VE	4669.134....	3	1	IVE.
4637.198....	10	30r	I A	4670.560*....	20	?	IVE
4637.505....	1—	4	III A	4671.100....	20	30r	I
4638.715....	10	3	IV E	4671.53d....	1—	4	IV A
4639.143....	20	40R	I A	4671.67....	1—	5	IV A
4639.380....	4	1—	IV E	4672.46....	1—	5	IV A
4639.593....	4	?	IV E	4672.68....	1	6	IV A
4641.0*....	1?	5?	IV A	4673.09....	1	8	IV A
4641.103....	80	80R	I	4673.971....	8	15	I A
4644.068....	1—	1	III A	4674.193....	2	.....	VE
4644.288....	1—	3	III A	4675.524....	8	15?	I A
4644.845*....	2	12	IV A	4677.064....	1	6	III A
4644.984....	4	10	I	4678.202....	1	10	III A
4645.767....	20	4	IV E	4678.95d....	3	15	III A
4646.400....	60	50r	I	4680.015....	1—	2	III A
4646.692....	1	6	II A	4680.205....	1	6	III A
4647.651....	1	4	III A	4680.742....	30	4	III E
4647.763....	3	1	IV E	4681.257....	2	.....	VE
4647.947....	3	15	III A	4683.447....	150	150R	I
4648.706....	1	6	IV A	4683.699....	1—	4	III A
4649.673....	80	60R	I	4684.039....	40	40R	I
4650.231....	3	.....	VE	4684.383....	2	12	III A
4650.303....	1—	5	IV A	4688.547....	6	20	III A
4651.020....	8	25r	I A	4690.35....	30	30	I
4651.189....	4	12	I A	4692.97....	2	6	II A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4696.440....	30	30	I	4763.62....	5	.....	VE
4697.19....	1—	2	III A	4763.87....	20	.....	VE
4698.30....	5	8	II	4767.80....	1—	6	III A
4699.81....	1—	5	III A	4768.96....	1	8	II A
4702.40 <sup>2</sup> ....	1—	3	III A	4769.31 <sup>2</sup> ....	2	.....	VE
4703.08 <sup>2</sup> ....	3	4	III	4770.20....	20	20	I
4703.57....	15	.....	VE	4771.06 <sup>2</sup> ....	2	4	III A
4703.87....	5	8	III	4772.26....	8	10	I
4706.54....	100	4	IV E	4772.88....	4	.....	VE
4706.955....	40	40	III	4774.18....	1	3	III A
4708.38 <sup>2</sup> ....	2	15	I	4775.04....	1—	3	III A
4709.53....	2	10	III A	4776.97....	1—	2	III A
4709.71....	20	1	II A	4777.72....	8	.....	VE
4710.92....	1	3	IV E	4778.40....	5	15	I A
4713.95....	8	20	I	4779.403....	80	40	I
4714.233....	3	10	III A	4780.51 <sup>2</sup> ....	2	15	III A
4715.586....	25	1	II A	4780.98....	1	4	III
4717.08*....	10	?	IV E	4781.47....	2	10	III A
4718.50....	1—	5	VE	4783.80....	10	.....	VE
4719.02....	100	8 or	III A	4786.06....	4	.....	VE
4721.23....	1	8	II	4786.45....	1	2	III A
4724.35....	20	1	II A	4787.40....	4	12	I A
4726.550....	8	12	IV E	4788.34*....	1	4	III A
4729.39 <sup>2</sup> ....	1	4	I	4789.41....	40	1	VE
4730.21....	1—	3	4789.72....	1	3	III A	
4731.41....	1	8	III A	4790.34....	1—	2	III A
4731.770....	60	40	III A	4792.62....	2	8	I A
4734.782....	2	6	I	4793.00....	1	5	III A
4734.903....	6	10	II A	4796.88 <sup>2</sup> ....	2	.....	VE
4736.20....	3	.....	I	4797.15 <sup>2</sup> ....	20	1	IV E
4739.88....	2	6	IV E	4798.04 <sup>2</sup> ....	2	2	III
4742.03....	1—	2	II A	4799.08....	1	5	III A
4742.39....	1	3	III A	4799.42 <sup>2</sup> ....	10	.....	VE
4744.91....	1	10	III A	4800.48d....	1	6	III A
4745.37....	2	10	III A	4801.89 <sup>2</sup> ....	1	2	III A
4749.560....	2	.....	III A	4805.12 <sup>2</sup> ....	2	.....	III E
4749.751....	30	30	VE	4806.17 <sup>2</sup> ....	1	3	III A
4751.26....	1	4	I	4806.62 <sup>2</sup> ....	15	30	III A
4752.53 <sup>2</sup> ....	1	4	III A	4809.36....	1	2	I A
4755.847....	15	20	1	4809.36....	1	2	III A
4758.49....	2	15	II A	4810.78 <sup>2</sup> ....	1	3	III A
4758.64....	2	10	II A	4811.04....	1	8	III A
4758.80....	1	8	III A	4811.34....	100	3	IV E
4759.10....	4	10	II A	4812.67....	2	4	III A
4759.34....	3	10	III A	4817.17....	3	.....	VE
4760.45....	5	10	II A	4818.96....	3	.....	VE
4761.56 <sup>2</sup> ....	1	6	I A	4819.64....	2	.....	VE
4761.76....	2	8	III A	4820.34....	30	1	IV E
4762.44 <sup>2</sup> ....	1	2	III A	4821.37 <sup>2</sup> ....	1	8	III A
					1	5	III A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4824.50.....	1	2	III A	4883.81.....	200	60	I
4825.48.....	150	5	IV E	4885.01.....	10	8	II
4826.27.....	1—	2	III A	4887.33.....	2	4	III A
4826.55.....	1	5	III A	4889.04.....	?	3	III
4827.57.....	2	3	III	4889.10.....	15	.....	VE
4827.74*	3	3	III	4890.70.....	30	.....	VE
4828.582*	6	2	VE ?	4891.07.....	100	50	I
4831.08.....	2	10	III A	4893.23.....	8	12	I
4832.28.....	20	3	III E	4896.93.....	200	100	I
4833.50.....	2	8	II A	4901.53.....	30	15	I
4834.452	1—	2	III A	4901.84.....	150	60	I
4835.322	2	5	III A	4902.03.....	6	.....	VE
4835.66.....	10	15	I	4905.61.....	1—	3	III A
4835.98.....	15	1	IV E	4907.26.....	3	5	II
4836.622	25	20	I	4907.78.....	3	6	II A
4839.0.....	1	4	III A	4908.23.....	1—	2	III A
4845.882	1	8	II A	4910.05d.....	10	30	I A
4846.322	1—	3	III A	4913.41.....	80	40	I
4847.122	1	4	III A	4914.37.....	15	.....	VE
4849.06.....	15	.....	VE	4916.43.....	1	5	III A
4853.33.....	8	15	I A	4920.68.....	60	2	IV E
4853.73.....	3	.....	VE	4921.14.....	3	6	II A
4854.22.....	1—	5	III A	4922.45.....	3	8	II A
4854.53.....	1—	5	II A	4923.72.....	1—	2	III A
4854.53.....	1	3	III A	4924.28.....	2	2	III
4854.722	2	.....	III A	4924.53*	300	150r	I
4855.31.....	10	15	VE	4926.702	1	8	III A
4855.61.....	1—	5	I	4927.63.....	1—	2	III A
4859.02.....	100	2	III A	4929.10.....	1	5	II A
4859.58.....	10	15	IV E	4930.22.....	1	2	III A
4861.77d.....	3	6	I	4930.72.....	2	.....	VE
4862.22d.....	1	3	III A	4940.30.....	2	20	III A
4863.552	2	4	III A	4941.18.....	1—	3	III A
4864.20.....	2	5	III A	4942.71.....	1	4	III A
4865.272	2	5	III A	4942.95.....	2	.....	VE
4866.74.....	60	.....	III A	4943.90*	3	1	VE
4867.84.....	3	.....	VE	4944.83.....	100	60	I
4869.27.....	4	.....	I	4945.64.....	1—	2	III A
4871.44.....	2	6	VE	4947.02.....	2	.....	VE
4874.37.....	2	5	III A	4950.29.....	3	6	III A
4875.73.....	2	8	II	4950.672	3	6	III A
4875.84.....	4	.....	III A	4952.462	6	15	III A
4876.12.....	3	.....	III A	4954.78.....	80	40	II
4879.79.....	10	10	II A	4958.10.....	2	.....	VE
4880.48.....	2	4	VE	4959.13*	60	6	IV E
4881.71.....	2	5	VE	4961.30.....	1—	3	III A
4882.88.....	3	.....	I	4961.39.....	10	.....	VE
			III A	4963.02.....	1—	4	III A
			I A	4963.33.....	12	8	II
			VE	4965.30.....	1—	6	III A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
4966.68 <sup>2</sup> . . .	1	10	III A	5063.68 <sup>2</sup> . . .	4	.....	VE
4968.10 . . .	1	2	III A	5068.35 . . .	1—	3	III A
4968.88 . . .	1—	2	III A	5069.07 . . .	1—	4	III A
4969.75 . . .	4	8	II A	5071.84 <sup>2</sup> . . .	6	8	II
4970.93 . . .	2	.....	VE	5073.84 <sup>2</sup> . . .	2	6	III A
4973.40 <sup>2</sup> . . .	1	4	III A	5074.40 <sup>2</sup> . . .	4	10	II A
4975.50 . . .	10	10	II	5074.83 . . .	1—	3	III A
4976.13 . . .	1—	2	III A	5076.53 <sup>2</sup> . . .	12	.....	VE
4977.36 . . .	1	4	III A	5077.111 . . .	2	.....	VE
4980.16 . . .	1—	5	III A	5079.05 <sup>2</sup> . . .	4	6	II
4980.88 <sup>2</sup> . . .	4	15	III A	5079.63 . . .	1	3	III A
4981.28 . . .	4	.....	VE	5081.18 . . .	1	8	II A
4982.80 . . .	3	8	III A	5082.06 . . .	1—	2	III A
4986.96 . . .	1—	2	III A	5089.52 . . .	1	4	III A
4987.13 <sup>2</sup> . . .	4	.....	VE	5089.71 . . .	3	4	II
4988.04 . . .	1	2	III A	5089.82 . . .	8	1	IVE
4988.65 . . .	3	8	II A	5090.28 . . .	1	4	III A
4989.19 . . .	1—	4	III A	5092.33 . . .	1	4	III A
4989.94 <sup>2</sup> . . .	2	.....	VE	5092.78 <sup>2</sup> . . .	30	1	IVE
4996.15 . . .	1—	6	III A	5096.51 . . .	3	.....	VE
4998.44 . . .	1—	5	III A	5100.08 . . .	1	4	III A
4998.55 . . .	4	.....	VE	5102.38 . . .	8	2	VE
4999.47 . . .	1—	6	III A	5102.38 . . .	8	2	III
5000.37 <sup>2</sup> . . .	3	.....	VE	5103.13 . . .	10	12	I
5005.83 . . .	2	6	III A	5105.19 . . .	3	.....	VE
5009.40 . . .	1—	4	III A	5105.32 . . .	8	10	I
5011.63 . . .	2	.....	VE	5106.02 <sup>2</sup> . . .	3	.....	VE
5014.51 <sup>2</sup> . . .	4	8	II A	5107.00 . . .	1—	3	III A
5019.76 <sup>1</sup> . . .	1	8	III A	5107.57 <sup>2</sup> . . .	15	.....	VE
5022.63 . . .	1	8	III A	5111.91 . . .	1—	5	III A
5024.55 . . .	1	4	III A	5114.49 . . .	1	4	III A
5026.42 . . .	2	6	II A	5115.72 . . .	2	10	III A
5027.12 <sup>2</sup> . . .	8	8	II	5123.75 <sup>2</sup> . . .	30	1	IVE
5027.82 . . .	2	.....	VE	5125.95 . . .	1	6	III A
5028.49 . . .	1—	5	III A	5130.58 <sup>2</sup> . . .	40	1—	VE
5029.42 <sup>2</sup> . . .	10	8	I	5132.32 <sup>2</sup> . . .	10	.....	VE
5030.74 . . .	1—	2	III A	5140.50 . . .	1	2	III A
5033.48 <sup>2</sup> . . .	3	.....	VE	5143.32 <sup>2</sup> . . .	3	.....	VE
5039.92 . . .	2	12	III A	5144.92 . . .	1	5	III A
5040.17 <sup>2</sup> . . .	8	10	II	5149.55 . . .	8	10	I
5042.53 . . .	1—	2	III A	5149.78 . . .	1—	5	III A
5045.03 . . .	1—	5	III A	5150.98 . . .	1—	3	III A
5045.52 <sup>1d</sup> * . . .	4	12 <sup>2</sup>	III A	5151.78 . . .	8	8	III
5046.16d . . .	1	5	III A	5153.41 <sup>2</sup> . . .	4	5	III
5051.06 <sup>2</sup> . . .	6	8	II	5161.68 <sup>2</sup> . . .	2	.....	VE
5051.62 <sup>2</sup> . . .	1	5	III A	5162.16 . . .	2	8	III A
5056.85 <sup>2</sup> . . .	15	15	I	5163.82 . . .	1	6	III A
5058.81 . . .	1	4	III A	5165.11 <sup>2</sup> . . .	10	.....	VE
5060.01 . . .	2	6	III A	5166.07 . . .	1	6	III A
				5166.29 . . .	1—	4	III A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
5167.88 <sup>2</sup>	3	.....	VE	5264.19	1	4	II A
5176.76 <sup>2</sup>	2	.....	VE	5266.67	1	6	III A
5178.75	3	8	II A	5267.47	1	5	III A
5179.74 <sup>2</sup>	25	1	IVE	5269.78 <sup>2</sup>	4	.....	VE
5181.17 <sup>2</sup>	5	.....	VE	5270.00 <sup>2</sup>	4	8	III A
5182.61 <sup>2</sup>	5	.....	VE	5273.39 <sup>2</sup>	50	2	IVE
5182.90	1—	4	III A	5276.27	1	5	III A
5187.05	2	8 <sup>2</sup>	II A?	5276.82 <sup>2</sup>	8	1	IVE
5188.22	1	3	III A	5284.11	1—	3	III A
5189.68	1	6	III A	5284.33	2	5	I A
5191.46 <sup>2</sup> *	100	6 <sup>2</sup>	IVE	5286.28	1	3	III A
5192.64 <sup>2</sup>	80	1—	VE	5286.72*	1	3	III A
5193.36	1—	3	III A	5288.15	2	6	I A
5195.58 <sup>2</sup>	3	3	III	5291.67 <sup>2</sup>	8	20	II A
5198.07	6	6	I	5293.18 <sup>2</sup>	100	3	IVE
5198.45	1	4	III A	5293.37	3	.....	VE
5199.73	4	6	I	5293.72	1—	2	III A
5200.12 <sup>2</sup>	10	1—	IVE	5295.38	1—	3	III A
5204.43 <sup>2</sup>	8	10	I	5298.88	3	6	I A
5205.07	1	3	III A	5300.58	2	4	III A
5209.02	1—	3	III A	5302.27 <sup>2</sup>	6	.....	VE
5209.87	1	4	III A	5302.60	2	5	III A
5212.37 <sup>2</sup>	30	1	IVE	5303.18 <sup>2</sup>	3	.....	VE
5213.20	8	8	I	5305.17	1—	4	III A
5213.08	1	4	III A	5305.69	1	3	III A
5214.27	2	8	I A	5306.44 <sup>2</sup>	4	.....	VE
5215.63 <sup>2</sup>	3	.....	VE	5308.26	2	6	III A
5216.58	1—	3	III A	5309.54	1—	3	III A
5217.71	1—	3	III A	5311.45 <sup>2</sup>	12	.....	VE
5221.54 <sup>2</sup>	2	.....	VE	5311.57	1—	5	III A
5225.02 <sup>2</sup>	5	.....	VE	5311.94	1—	6	III A
5228.38 <sup>2</sup>	6	.....	VE	5313.84	1	2	III A
5230.19	2	4	III A	5314.35	1	6	III A
5233.01	1	2	III A	5316.58 <sup>2</sup>	3	.....	VE
5234.15 <sup>2</sup>	50	1	VE	5317.36	1	6	III A
5234.57	1	2	III A	5319.80 <sup>2</sup>	125	4	IVE
5236.68	1—	3	III A	5320.78	3	5	III
5239.01	1	2	III A	5324.58	3	4	III
5239.71*	1	6	III A	5326.49	1—	3	III A
5239.75*	15	1—	IVE	5327.16	1	3	III A
5240.58	1—	4	III A	5329.88	1	3	III A
5241.58	1—	4	III A	5332.44	2	4	III A
5245.90	1—	4	III A	5334.33	5	10	I A
5248.19	1—	3	III A	5334.52	1	3	III A
5249.30	2	5	I A	5336.49 <sup>2</sup>	8	.....	VE
5249.54 <sup>2</sup>	100	1	VE	5336.84	2	8	I A
5250.77 <sup>2</sup>	8	.....	VE	5340.41	1	3	III A
5255.47 <sup>2</sup>	50	3	IVE	5343.20	1	4	III A
5260.88	1—	4	III A	5343.64	3	4	III
5263.96	1	2	III A	5345.65 <sup>2</sup>	5	.....	VE

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
5349.26.....	1	2	III A	5429.30.....	5	6	III
5349.57 <sup>2</sup> .....	4	8	I A	5430.77.....	5	3	III
5350.11.....	1—	3	III A	5431.53.....	40	.....	VE
5350.70.....	1	2	III A	5432.37.....	3	.....	VE
5356.92 <sup>2*</sup> .....	15	.....	VE	5433.72.....	1	3	III A
5357.89.....	1—	3	III A	5434.43.....	4	4	III
5360.08.....	1—	4	III A	5436.80.....	2	2	III
5361.17.....	3	.....	VE	5437.58d.....	2	2	III
5361.47 <sup>2</sup> .....	60	4	IV E	5438.65.....	2	2	III
5361.88.....	2	3	III	5440.49.....	1	5	III A
5362.87d <sup>2</sup> .....	2	3	III	5441.43 <sup>2</sup> .....	2	.....	VE
5363.67.....	2	5	II A	5441.52.....	1	5	III A
5365.12 <sup>2</sup> .....	2	.....	VE	5442.28.....	40	3	IV E
5367.00.....	1—	4	II A	5443.67.....	1—	2	III A
5371.39.....	2	3	III	5444.56.....	1	2	III A
5371.92.....	20	.....	VE	5444.92.....	4	2	III
5373.68.....	2	3	III	5445.19.....	2	8	III A
5377.02.....	1	4	III A	5447.24 <sup>*</sup> .....	12	4	III
5377.78.....	5	8	I	5447.55.....	6	1	IV E
5378.27.....	2	4	III A	5448.62.....	2	1	III
5379.31.....	1	2	III A	5449.26 <sup>*</sup> .....	15	3	III
5379.62.....	1	2	III A	5451.13.....	100	2	IV E
5380.61.....	3	5	III	5452.10.....	1	6	III A
5381.75.....	2	4	III A	5453.90.....	3	2	III
5383.9.....	2	.....	VE	5455.82.....	20	1	IV E
5384.00.....	1	3	III A	5458.00.....	4	3	III
5385.88 <sup>2</sup> .....	15	1—	IV E	5461.08.....	1—	3	III A
5388.04.....	1—	6	II A	5461.67.....	1	8	II A
5398.11.....	2	6	I A	5462.85.....	1—	6	III A
5400.15 <sup>2</sup> .....	4	2	III	5467.52.....	2	4	III A
5402.90 <sup>2</sup> .....	5	4	III	5468.06.....	2	4	III A
5406.15 <sup>2</sup> .....	3	.....	VE	5469.41.....	2	3	III
5409.59.....	1	2	III A	5470.42.....	5	5	III
5411.94.....	5	15	II A	5473.08.....	6	.....	VE
5412.95.....	2	5	III A	5474.30.....	1	4	III A
5414.74.....	3	1	III	5474.72 <sup>3</sup> .....	10	.....	VE
5415.00.....	1	6	II A	5476.23.....	1	2	III A
5415.31.....	5	12	II A	5478.03.....	1	10	II A
5416.31 <sup>2</sup> .....	15	1	IV E	5478.61.....	15	8	III
5416.89.....	2	3	III	5483.37.....	1—	3	III A
5418.22.....	1	2	III A	5483.95 <sup>3</sup> .....	3	3	III
5420.65.....	6	10	III	5484.89.....	1	6	III A
5421.55.....	20	3	IV E	5485.04 <sup>3</sup> .....	8	.....	VE
5422.49.....	2	2	III	5485.72 <sup>3</sup> .....	80	.....	VE
5422.66.....	1	6	I A	5487.81.....	1	2	III A
5423.59.....	3	5	III	5490.47d.....	1	2	III A
5424.07.....	3	2	III	5492.28 <sup>3</sup> .....	8	3	III
5425.77.....	1	3	III A	5493.12.....	1	3	III A
5426.41.....	1	2	III A	5493.37 <sup>3</sup> .....	4	3	III
5428.82.....	1	1	III	5494.01 <sup>3</sup> .....	10	.....	VE

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
5406.42 <sup>3</sup> .....	3	3	III	5588.39 <sup>3</sup> .....	2	3	III
5406.92.....	1	3	III A	5588.84 <sup>3</sup> *.....	4	.....	VE
5408.86 <sup>3</sup> .....	5	4	III	5592.65 <sup>3</sup> .....	3	1	III
5501.50 <sup>3</sup> .....	20	8	III	5594.43 <sup>3</sup> .....	150	1	VE
5504.30.....	1—	2	III A	5601.41 <sup>3</sup> .....	20	4	III
5507.20.....	2	8	II A	5601.91 <sup>3</sup> .....	20	20	III
5508.41 <sup>3</sup> .....	5	.....	VE	5602.63 <sup>3</sup> .....	3	.....	VE
5511.93 <sup>3</sup> .....	2	2	III	5603.19.....	3	5	III
5514.75 <sup>3</sup> .....	2	5	III A	5603.63 <sup>3</sup> .....	5	.....	VE
5515.07.....	2	2	III	5604.44.....	1—	3	III A
5516.29 <sup>3</sup> .....	8	8 <sup>2</sup>	III	5605.74.....	1—	3	III A
5518.40 <sup>3</sup> .....	3	6	II A	5606.69.....	1	4	III A
5519.34.....	2	2	III	5612.08.....	1—	4	III A
5522.13.....	1	2	III A	5614.45.....	1	3	III A
5523.88 <sup>3</sup> .....	2	15	I A	5615.20 <sup>3</sup> .....	6	4	III
5525.74 <sup>3</sup> .....	60	30	II	5615.68.....	1—	4	III A
5528.36 <sup>3</sup> .....	5	.....	VE	5616.20.....	1—	2	III A
5529.07.....	10	10	I	5617.67 <sup>3</sup> .....	4	.....	VE
5532.08.....	3	3	III	5618.67.....	1—	2	III A
5533.14.....	1—	4	III A	5619.58.....	1—	6	II A
5533.82 <sup>3</sup> d*.....	40	15	II	5620.51d*.....	500	100	I
5535.27 <sup>3</sup> .....	4	.....	VE	5623.70.....	1	2	III A
5535.45.....	1—	2	III A	5624.22.....	1	3	III A
5536.37 <sup>3</sup> .....	2	3	III	5625.71 <sup>3</sup> .....	4	.....	VE
5537.28d.....	3	4	III	5626.65.....	1—	3	III A
5537.76 <sup>3</sup> .....	2	.....	VE	5631.65 <sup>2</sup> .....	2	4	III A
5538.23.....	1—	2	III A	5635.74 <sup>3</sup> .....	30	10	III
5538.79.....	1	1	III	5636.27.....	1	2	III A
5543.24 <sup>3</sup> .....	30	12	III	5638.67.....	1—	2	III A
5544.83.....	2	10	I A	5639.54 <sup>3</sup> .....	30	30	III
5545.00 <sup>3</sup> .....	4	.....	VE	5640.50 <sup>3</sup> .....	1	8	III A
5546.60.....	1	5	I A	5641.54.....	1—	3	III A
5548.45 <sup>3</sup> .....	8	1	IV E	5643.24 <sup>3</sup> .....	1	3	III A
5550.09 <sup>3</sup> .....	2	.....	VE	5646.79.....	1—	2	III A
5552.87 <sup>3</sup> .....	4	2	III	5647.98 <sup>3</sup> .....	4	2	III
5557.62.....	4	.....	VE	5651.50.....	2	4	III A
5561.16 <sup>3</sup> .....	50	50	I	5652.65.....	1	3	III A
5562.04.....	1	6	III A	5653.55 <sup>3</sup> .....	10	12	III
5568.53.....	1—	2	III A	5659.45.....	1—	2	III A
5569.95 <sup>3</sup> .....	4	.....	VE	5659.77 <sup>3</sup> .....	5	.....	VE
5574.66 <sup>3</sup> .....	2	2	III	5662.44 <sup>3</sup> .....	4	3	III
5575.50 <sup>3</sup> .....	15	25	III	5663.28.....	1—	6	II A
5576.70 <sup>3</sup> .....	10	4	III	5663.56 <sup>3</sup> .....	2	1	III
5577.75 <sup>3</sup> .....	10	6	III	5665.25 <sup>3</sup> .....	4	2	III
5581.59 <sup>3</sup> .....	3	.....	VE	5668.85 <sup>3</sup> .....	15	.....	VE
5581.94.....	1	6	III A	5669.77 <sup>3</sup> .....	30	60	II A
5586.54.....	1—	2	III A	5672.78.....	1	3	III A
5587.59 <sup>3</sup> .....	8	8	III	5673.12.....	1	2	III A
5587.95 <sup>3</sup> .....	3	.....	VE	5674.83 <sup>3</sup> .....	3	10	III A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
5675.92 <sup>3</sup> . . .	250	100	I	5746.87 <sup>3</sup> . . .	2	10	III A
5676.35 <sup>3</sup> . . .	30	20	III	5748.15 <sup>3</sup> . . .	4	3	III
5677.40 . . .	1—	6	III A	5749.14 <sup>3</sup> . . .	25	40	III
5678.83 . . .	1—	4	III A	5749.63 <sup>3</sup> . . .	12	30	I A
5681.16 <sup>3</sup> . . .	4	15	III A	5750.62 . . .	1—	2	III A
5683.27 . . .	1	2	III A	5751.86 <sup>3</sup> . . .	1—	2	III A
5685.10 . . .	1	2	III A	5752.36 <sup>3</sup> . . .	1	10	III A
5686.55 . . .	3	5	III	5753.53 <sup>3</sup> . . .	3	—	VE
5688.50 <sup>3</sup> . . .	150	1	VE	5753.95 <sup>2</sup> . . .	4	4	III
5689.50 <sup>3</sup> . . .	4	3	III	5754.10 <sup>3</sup> . . .	1	2	III A
5691.72 <sup>3</sup> . . .	1	3	III A	5559.44 <sup>3</sup> . . .	1	1	III
5693.88 <sup>3</sup> . . .	1—	5	III A	5761.23 <sup>3</sup> . . .	1	2	III A
5695.18 <sup>3</sup> . . .	5	10	III A	5761.67 <sup>3</sup> . . .	4	—	VE
5695.65 <sup>3</sup> d . . .	1	3	III A	5762.06 <sup>3</sup> . . .	6	8	III
5698.89 . . .	3	—	VE	5762.36 <sup>3</sup> . . .	2	2	III
5699.71 <sup>3</sup> . . .	1	2	III A	5764.20 <sup>3</sup> . . .	2	5	III A
5701.54 <sup>3</sup> . . .	5	4	III	5765.44 <sup>3</sup> . . .	2	4	III A
5702.25 <sup>3</sup> . . .	20	—	VE	5767.33 <sup>3</sup> . . .	5	5	III
5702.49 . . .	1—	3	III A	5769.86 <sup>3</sup> . . .	2	—	VE
5704.33 . . .	1	3	III A	5770.50 <sup>3</sup> . . .	5	—	VE
5704.54 . . .	1	4	III A	5771.42 <sup>3</sup> . . .	1	3 5	III A
5706.20 <sup>3</sup> * . . .	15	—	VE	5772.14 <sup>3</sup> . . .	5	20	I A
5707.82 . . .	1—	3	III A	5773.50 . . .	1—	2	III A
5708.10 . . .	1—	3	III A	5773.89 <sup>3</sup> d . . .	2	3	III
5708.28 <sup>3</sup> . . .	40	1	IV E	5776.10 <sup>3</sup> . . .	30	50	I
5710.22 <sup>3</sup> . . .	3	3	III	5776.54 . . .	1	2	III A
5711.61d . . .	1	6	III A	5777.93 <sup>3</sup> . . .	1	1	III
5712.94 . . .	1—	10	III A	5780.58 . . .	2	2	III
5713.03 <sup>3</sup> . . .	1	—	VE	5781.30 <sup>3</sup> . . .	1	5	III A
5713.85 <sup>3</sup> . . .	1	2	III A	5783.64 <sup>3</sup> * . . .	3	1	III
5714.78 . . .	1	2	III A	5784.06 <sup>3</sup> . . .	25	25	I
5717.61 <sup>3</sup> . . .	1	1	III	5786.71 . . .	1—	2	III A
5718.12 <sup>3</sup> . . .	12	—	VE	5788.19 <sup>3</sup> . . .	30	30	I
5719.08 <sup>3</sup> . . .	6	3	III	5788.89 <sup>3</sup> . . .	1	1	III
5720.09 . . .	1—	6	III A	5791.47 <sup>3</sup> . . .	2	2	III
5723.87 <sup>3</sup> . . .	1	1	III	5792.41 . . .	2	2	III
5726.82 <sup>3</sup> . . .	6	—	VE	5795.15 <sup>3</sup> . . .	3	—	VE
5727.86 <sup>3</sup> . . .	4	30	III A	5796.33 . . .	1	3	III A
5729.30 <sup>3</sup> . . .	60	60	I	5800.07 <sup>3</sup> . . .	2	8 <sup>2</sup>	III A
5729.87 . . .	1—	2	III A	5803.06 . . .	1	3	III A
5730.29 <sup>3</sup> . . .	2	10	III A	5803.66 . . .	1—	3	III A
5731.09 <sup>3</sup> . . .	3	8	III A	5804.01 <sup>3</sup> . . .	60	—	VE
5734.20 <sup>3</sup> . . .	2	20	III A	5806.41 <sup>3</sup> . . .	2	2	III
5738.93 <sup>3</sup> . . .	3	4	III	5809.24 <sup>3</sup> . . .	8	6	III
5739.97 <sup>3</sup> . . .	4	—	VE	5811.58 <sup>3</sup> . . .	12	—	VE
5740.86 <sup>3</sup> . . .	15	1	IV E	5813.19 <sup>3</sup> . . .	1	3	III A
5742.08 <sup>3</sup> . . .	4	—	VE	5813.87 <sup>3</sup> . . .	25	25	III
5743.23 <sup>3</sup> . . .	3	—	VE	5815.43 <sup>3</sup> . . .	4	5	III
5744.34 . . .	1	3	III A				
5744.77 <sup>3</sup> . . .	4	—	VE				

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
5816.87	1	2	III A	5882.75 <sup>3</sup>	4		VE
5820.36 <sup>3</sup>	8	25	II A	5883.28 <sup>3</sup>	15	30	III A
5823.30 <sup>d</sup>	2		VE	5883.66 <sup>3*</sup>	1	15	III A
5823.76	1	2	III A	5886.22 <sup>3</sup>	5	8	III
5824.00	1	2	III A	5887.17	1	2	III A
5825.11 <sup>3</sup>	1	15	II A	5887.80 <sup>3</sup>	25	50	I A
5825.87 <sup>3</sup>	8		VE	5890.43	4	3	III
5826.75 <sup>3</sup>	20	40	I A	5891.52 <sup>3</sup>	15		VE
5829.26	1	3	III A	5892.6	2	2	III
5829.58	2	2	III	5895.57	3	8	III A
5829.75	1	15	II A	5896.65	1	3	III A
5830.72 <sup>3</sup>	3	8	III A	5897.48	1	4	III A
5833.11	1	2	III A	5899.15	2	5	III A
5833.35	1	2	III A	5899.50 <sup>3</sup>	5	10	III A
5834.72	1	2	III A	5900.43 <sup>3</sup>	5	2 <sup>2</sup>	III
5837.15 <sup>3</sup>	2	15	III A	5901.59	1	8	III A
5839.08 <sup>3</sup>	2	40	I A	5902.07 <sup>3</sup>	3	6	III A
5841.90	1	2	III A	5905.80 <sup>3</sup>	2	3	III
5842.37 <sup>3</sup>	8	1	IV E	5906.65 <sup>3</sup>	6	1	IV E
5842.93	1	2	III A	5908.10 <sup>3</sup>	1	1	III
5844.66 <sup>3</sup>	4	25	III A	5909.02	1	2	III A
5845.90 <sup>3</sup>	4	8	III A	5909.86 <sup>3</sup>	5		VE
5846.32 <sup>3</sup>	2		VE	5910.63	1	3	III A
5847.59 <sup>3</sup>	2	8	III A	5914.39 <sup>3</sup>	8	10	III
5849.50 <sup>3</sup>	1	1	III	5914.66 <sup>3</sup>	1	12	III A
5852.01 <sup>3</sup>	1	3	III A	5914.91 <sup>*</sup>	1	10	III A
5853.00 <sup>3</sup>	1	2	III A	5919.31 <sup>3</sup>	1	2	III A
5853.21	1	2	III A	5919.81 <sup>3</sup>	3	8	III A
5853.87	1	2	III A	5921.20 <sup>3</sup>	10	40	I A
5856.66 <sup>3</sup>	2	4	III A	5922.79 <sup>3</sup>	8	15	III A
5857.50 <sup>3</sup>	4		VE	5924.69	1	2	III A
5858.88 <sup>3</sup>	15	30	III A	5926.50 <sup>3</sup>	1	2	III A
5859.36	1	15	II A	5927.94 <sup>3</sup>	2	2	III
5859.68 <sup>3</sup>	2	2	III	5928.93 <sup>3</sup>	4	5	III
5861.15 <sup>3</sup>	1	1	III	5929.56	1	10	III A
5865.03 <sup>3</sup>	3		VE	5931.43	3	4	III
5865.61	1	3	III A	5932.47	1	3	III A
5867.05 <sup>d</sup>	8	15	III A	5934.89 <sup>*</sup>	5	10	III A
5867.57	3	5	III	5935.44	4	8	III A
5868.88 <sup>3</sup>	10	5	III	5939.73 <sup>3*</sup>	4	4	III
5869.57 <sup>3</sup>	4	40	II A	5941.39	1	5	III A
5870.98 <sup>3</sup>	5	10	III A	5943.21 <sup>3</sup>	3		VE
5873.33 <sup>3</sup>	2	15	II A	5946.20 <sup>3</sup>	2	2	III
5875.82 <sup>d</sup>	2	5	III A	5947.36 <sup>3</sup>	2		VE
5876.34 <sup>3</sup>	4	20	III A	5948.61 <sup>3</sup>	1	2	III A
5877.79 <sup>3</sup>	4		VE	5949.61 <sup>3</sup>	15	30	III A
5878.20 <sup>3</sup>	1	1	III	5950.47 <sup>3</sup>	2	8	III A
5878.88 <sup>3</sup>	1	4	III A	5953.05 <sup>3</sup>	1	1	III
5879.76 <sup>3</sup>	1	2	III A	5954.47 <sup>3</sup>	1	1	III
5880.25 <sup>3</sup>	3	8	III A	5955.16 <sup>3</sup>	1	3	III A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
5955.88 <sup>3</sup> . . . .	3	8	II A	6025.54 <sup>3</sup> . . . .	5	25	II A
5961.15 <sup>3</sup> . . . .	6	20	III A	6029.20 <sup>3</sup> . . . .	1	2	III A
5962.30 <sup>3</sup> . . . .	1	2	III A	6031.28 <sup>3</sup> . . . .	5	.....	VE
5963.22 <sup>3</sup> . . . .	3	4	III	6032.87 . . . .	1	2	III A
5966.01 <sup>3</sup> . . . .	1—	30	II A	6033.30 <sup>3</sup> . . . .	12	15	III
5966.36 <sup>3</sup> . . . .	2	8	III A	6034.25 <sup>3</sup> . . . .	6	.....	VE
5966.74 <sup>3</sup> . . . .	1	3	III A	6049.92 <sup>3</sup> . . . .	2	30	IA
5967.85 <sup>3</sup> . . . .	1	2	III A	6050.50 <sup>3</sup> . . . .	3	5	III
5968.30 <sup>3</sup> . . . .	3	15	II A	6051.88 <sup>3</sup> . . . .	2	.....	VE
5972.47 <sup>3</sup> . . . .	2	4	III A	6053.83 <sup>3</sup> . . . .	2	3	III
5974.22 <sup>3</sup> . . . .	5	15	III A	6054.47 <sup>3</sup> . . . .	3	4	III
5974.57 <sup>3</sup> . . . .	4	15	III A	6056.99 <sup>3</sup> . . . .	4	30	II A
5975.48 <sup>3</sup> . . . .	1	1	III	6058.33 <sup>3</sup> . . . .	4	5	III
5977.42 <sup>3d</sup> . . . .	4	6	III	6061.05 <sup>3</sup> . . . .	4	15	III A
5978.82 <sup>3</sup> . . . .	1	5	III A	6065.18 <sup>3d</sup> . . . .	3	4	III
5981.56 <sup>3</sup> . . . .	1—	2	III A	6065.74 . . . .	1—	3	III A
5982.36 . . . .	1	2	III A	6066.07 <sup>3</sup> . . . .	60	60	III
5984.32 <sup>3</sup> . . . .	2	2	III	6067.00 <sup>3</sup> . . . .	2	15	III A
5988.16 <sup>3</sup> . . . .	4	12	III A	6068.72 . . . .	2	2	III
5988.81 <sup>3</sup> . . . .	1	2	III A	6071.52 . . . .	1—	4	III A
5989.33 <sup>3</sup> . . . .	6	.....	VE	6071.71 <sup>3</sup> . . . .	20	20	II A
5990.21 <sup>3</sup> . . . .	3	3	III	6073.09 <sup>3</sup> . . . .	2	2	III
5990.70 <sup>3</sup> . . . .	2	1	III	6073.96 <sup>3</sup> . . . .	40	50	I
5994.77 <sup>3</sup> . . . .	30	40	III	6074.43 <sup>3</sup> . . . .	4	25	II A
5996.47 <sup>3</sup> . . . .	15	25	III	6081.53 <sup>3</sup> . . . .	1	1	III
5996.95 <sup>3</sup> . . . .	2	2	III	6082.02 <sup>3</sup> . . . .	2	25	IA
5998.32 <sup>3</sup> . . . .	1	2	III A	6083.12 . . . .	1—	2	III A
5998.80 <sup>3</sup> . . . .	2	2	III	6084.62 <sup>3</sup> . . . .	6	12	III A
5999.50 <sup>3</sup> . . . .	1	1	III	6086.94 <sup>3</sup> . . . .	3	3	III
5999.84 . . . .	1—	15	III A	6088.01 <sup>3</sup> . . . .	3	15	III A
6000.09 <sup>3</sup> . . . .	4	30	II A	6090.86 . . . .	1—	4	II A
6001.95 . . . .	2	10	III A	6091.58 <sup>3</sup> . . . .	2	2	III
6002.33 . . . .	3	4	III	6097.79 <sup>3</sup> . . . .	4	8	III A
6002.52 . . . .	4	4	III	6098.20 <sup>3</sup> . . . .	1	2	III A
6004.33 <sup>3</sup> . . . .	1—	3	III A	6099.18 <sup>3</sup> . . . .	1	2	III A
6005.43 <sup>3</sup> . . . .	1	1	III	6100.19 . . . .	1	10	III A
6006.44 <sup>3</sup> . . . .	3	20	III A	6101.74 <sup>3</sup> . . . .	10	20	III A
6007.67 <sup>3</sup> . . . .	80	100	II	6104.06 <sup>3</sup> . . . .	2	.....	VE
6009.29 <sup>3</sup> . . . .	3	.....	VE	6107.74 <sup>3</sup> . . . .	1	12	III A
6010.86 <sup>3</sup> . . . .	2	1	III	6108.42 <sup>3</sup> . . . .	4	.....	VE
6011.50 <sup>3</sup> . . . .	1	4	III A	6109.68 <sup>3*</sup> . . . .	2	2	III
6013.98 <sup>3</sup> . . . .	1	1	III	6109.68 <sup>3</sup> . . . .	10	40	IA
6014.92 . . . .	1—	4	III A	6111.37 <sup>3</sup> . . . .	1	1	III
6015.33 <sup>3</sup> . . . .	3	4	III	6113.47 <sup>3</sup> . . . .	3	3	III
6017.21 <sup>3</sup> . . . .	2	6	III A	6113.98 <sup>3</sup> . . . .	1	2	III A
6020.24 . . . .	3	5	III	6116.50 . . . .	1	5	III A
6022.63 . . . .	2	8	III A	6119.86 <sup>3</sup> . . . .	1	3	III A
6023.35 . . . .	2	.....	VE	6122.16 <sup>3</sup> . . . .	4	.....	VE
6023.56 . . . .	3	8	III A	6122.99 <sup>3</sup> . . . .	4	10	III A
6024.68 . . . .	1—	2	III A	6125.30 . . . .	1—	6	III A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
6126.17	1	2	III A	6196.21 <sup>3d</sup>	3	4	III
6128.50 <sup>3</sup>	1—	2	II A	6197.70	1	2	III A
6129.20 <sup>3</sup>	1	1	III	6201.74 <sup>3</sup>	4	—	VE
6130.60 <sup>3</sup>	4	15	II A	6205.44	1	8	III A
6131.82 <sup>3</sup>	2	—	VE	6206.07 <sup>3</sup>	1	—	VE
6132.80	1—	4	III A	6206.65	1	2	III A
6133.51 <sup>3</sup>	3	{	VE	6207.06 <sup>3</sup>	2	—	VE
		1	III	6208.23 <sup>3</sup>	15	50	III A
6133.92 <sup>3</sup>	2	—	VE	6210.70 <sup>3</sup>	1	—	VE
6135.82 <sup>3</sup>	2	4	III A	6212.79 <sup>3</sup>	2	3	III
6137.37 <sup>3</sup>	3	5	III	6216.71 <sup>3</sup>	5	12	III A
6141.86 <sup>3</sup>	2	1	III	6218.16 <sup>3</sup>	2	3	III
6142.42 <sup>3</sup>	2	10	III A	6219.79	2	5	III A
6144.54 <sup>3</sup>	2	1	III	6221.15 <sup>3</sup>	2	2	III
6146.12	1—	3	III A	6222.15 <sup>3</sup>	3	15	III A
6148.13	1—	15	III A	6223.19	1—	3	III A
6148.60	3	40	I A	6223.38 <sup>3</sup> *	50	40	III
6149.28 <sup>3</sup>	20	100	II A	6225.25	1	30	I A
6150.23 <sup>3</sup>	3	25	III A	6226.50 <sup>3</sup>	20	50	II A
6152.75 <sup>3</sup>	1	1	III	6227.18	2	8	III A
6155.06 <sup>3</sup>	15	30	III A	6230.30	1	1	III
6156.18 <sup>3d</sup>	8	20	II A	6237.34	1—	25	I A
6156.57 <sup>3</sup>	3	—	VE	6238.49 <sup>3</sup> *	5	2	III
6156.90 <sup>3</sup>	2	20	II A	6240.16	1	10	III A
6157.83 <sup>3</sup>	6	1	IV E	6243.31 <sup>3</sup>	1	—	VE
6161.26*	5	50	III A	6244.06 <sup>3</sup>	30	50	II
6161.52	2	—	VE	6246.83	1—	1	III A
6162.38 <sup>3</sup>	6	—	VE	6248.27 <sup>3</sup>	2	—	VE
6165.10	2	—	VE	6248.95	1—	3	III A
6165.33	2	4	III A	6250.41 <sup>3</sup>	1	—	VE
6165.63 <sup>3</sup>	6	40	III A	6251.82 <sup>3</sup>	2	3	III
6166.67 <sup>3</sup>	3	—	VE	6252.73	1	5	III A
6166.76*	2	20	III A	6256.70	1	2	III A
6167.40	1—	20	II A	6257.33	3	50	II A
6168.06 <sup>3</sup>	2	—	VE	6257.53	8	30	III A
6169.15 <sup>3</sup>	2	3	III	6258.74 <sup>3</sup>	3	—	VE
6170.49 <sup>3</sup>	5	—	VE	6260.67 <sup>3d</sup>	2	4	III A
6174.30*	2	50	I A	6263.23 <sup>3d</sup> *	3	4	III
6176.08 <sup>3</sup>	3	2	III	6265.12	1—	3	III A
6178.21 <sup>3</sup>	1	2	III A	6265.59	1—	4	III A
6178.59 <sup>3</sup>	40	60	III	6269.40 <sup>3</sup>	6	15	III A
6181.57 <sup>3</sup>	1—	1	III A	6270.26 <sup>3d</sup> *	2	10	III A
6182.98 <sup>3</sup>	4	—	VE	6271.28	1—	5	III A
6183.87 <sup>3</sup>	6	—	VE	6271.69 <sup>3</sup>	1—	—	VE
6184.18	1—	2	III A	6277.30 <sup>3</sup>	3	—	VE
6184.97	1—	15	III A	6278.93 <sup>3</sup>	1	1	III
6186.99	2	2	III	6279.36 <sup>3</sup>	2	2	III
6189.46	2	2	III	6279.66 <sup>3</sup>	2	1	III
6191.67*	3	10	III A	6282.00 <sup>3</sup>	10	25	II A
6195.11	1	1	III	6283.94 <sup>3</sup>	1	12	II A

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
6285.78 <sup>3</sup> .....	15	40	II A	6348.78 <sup>3</sup> .....	2	30	II A
6287.19 <sup>3</sup> .....	1	.....	VE	6349.83 <sup>3</sup> .....	1	.....	VE
6288.03 <sup>3</sup> .....	2	80	I	6351.06 <sup>3</sup> .....	1	.....	VE
6291.48.....	1—	6	VE	6353.57 <sup>3</sup> .....	2	6	III A
6291.09 <sup>3</sup> .....	1	.....	II A	6354.25 <sup>3</sup> .....	1	1	III
6292.84 <sup>3</sup> .....	3	.....	VE	6354.75 <sup>3</sup> .....	1	.....	VE
6293.59 <sup>3</sup> .....	3	8	III A	6355.95 <sup>3</sup> .....	6	12	III A
6294.26.....	1—	10	II A	6356.54 <sup>3</sup> .....	4	8	III A
6294.45.....	2	10	II A	6360.11.....	1—	30	I A
6296.05.....	1	1	III	6360.86 <sup>3</sup> .....	1	15	II A
6297.07 <sup>3</sup> .....	15	30	II A	6361.44 <sup>3</sup> .....	2	.....	VE
6298.41 <sup>3</sup> .....	3	.....	VE	6362.10 <sup>3</sup> *	4	2	III
6300.44 <sup>3</sup> .....	2	30	II A	6363.04 <sup>3</sup> .....	2	8	III A
6300.98 <sup>3</sup> .....	1	.....	VE	6365.56 <sup>3</sup> .....	3	.....	VE
6301.95.....	5	6	III	6372.80 <sup>3</sup> .....	3	5	III
6302.20.....	1—	8	II A	6375.06 <sup>3</sup> .....	8	8	III
6304.38.....	1—	2	III A	6380.40.....	1	20	I A
6304.68.....	1	2	III A	6382.06 <sup>3</sup> .....	8	.....	VE
6307.02.....	4	60	III A	6383.17 <sup>3</sup> .....	4	10	III A
6308.25.....	8	10	III A	6385.17 <sup>3</sup> *	150	300	I A
6310.48 <sup>3</sup> .....	80	150	I	6386.94 <sup>3</sup> .....	1	2	III A
6312.70 <sup>3</sup> *	2	4	III A	6390.00.....	3	.....	VE
6313.26 <sup>3</sup> .....	1	.....	III	6394.80.....	2	5	III A
6313.40.....	1—	12	VE	6395.88 <sup>3</sup> .....	1	5	III A
6314.57.....	1	2	III A	6396.88 <sup>3</sup> .....	2	3	III
6315.84.....	1	3	III A	6397.84.....	1	100	I A
6316.86.....	1	2	III A	6402.75 <sup>3</sup> .....	1	1	III
6319.67 <sup>3</sup> .....	2	.....	VE	6403.22 <sup>3</sup> .....	4	8	III A
6321.22 <sup>3</sup> .....	4	50	III A	6407.62.....	1	2	III A
6322.87 <sup>3</sup> .....	3	3	III	6408.49.....	1	25	I A
6324.77.....	2	4	III A	6410.58 <sup>3</sup> .....	2	10	III A
6324.90.....	1	4	III A	6414.04 <sup>3</sup> .....	3	6	III A
6325.28.....	1—	15	II A	6415.37 <sup>3</sup> .....	2	3	III
6326.93 <sup>3</sup> .....	4	4	III	6416.80 <sup>3</sup> .....	1	1	III
6328.47 <sup>3</sup> .....	2	.....	VE	6418.93.....	2	.....	VE
6330.14 <sup>3</sup> .....	2	.....	VE	6419.19.....	2	3	III
6331.87 <sup>3</sup> .....	1	3	III A	6420.71 <sup>3</sup> .....	3	5	III
6333.80 <sup>3</sup> .....	3	3	III	6425.80 <sup>3</sup> .....	3	.....	VE
6336.55 <sup>3</sup> *	1	8	III A	6428.66 <sup>3</sup> .....	6	.....	VE
6338.57.....	1—	8	III A	6429.84.....	3	12	III A
6338.83 <sup>3</sup> .....	1	.....	VE	6431.16 <sup>3</sup> .....	2	2	III
6340.66.....	1—	20	II A	6431.71 <sup>3</sup> .....	4	10	III A
6341.47 <sup>3</sup> *	6	5	III	6432.66 <sup>3</sup> .....	12	30	II A
6343.07.....	1	2	III A	6433.22 <sup>3</sup> .....	1	.....	VE
6346.54.....	4	6	III	6435.00 <sup>3</sup> .....	2	.....	VE
6347.81 <sup>3</sup> .....	2	6	III A	6439.18 <sup>3</sup> *	6	5	III
				6439.75 <sup>3</sup> *	2	2	III
				6441.45.....	1—	3	III A
				6442.98 <sup>3</sup> .....	1	1	III
				6445.80 <sup>3</sup> .....	1	.....	VE

## THE SPECTRUM OF NEODYMIUM

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TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
6448.82 <sup>3</sup>	2	4	III A	6555.83	1—	2	III A
6451.21 <sup>3*</sup>	8	15	III A	6558.95 <sup>3</sup>	2		VE
6454.80	6	8	III	6563.94 <sup>3</sup>	2		VE
6455.06 <sup>3</sup>	4	10	III A	6565.41	1	1	III
6456.22	1	40	I A	6571.80 <sup>3</sup>	1	2	III A
6457.14 <sup>3</sup>	6	15	II A	6572.66 <sup>3</sup>	2		VE
6457.90 <sup>3</sup>	1		VE	6577.73 <sup>3</sup>	2	2	III
6458.98 <sup>3</sup>	2	10	III A	6579.60	3	3	III
6459.46	1—	1	III A	6580.90 <sup>3</sup>	2		VE
6460.32	1—	4	III A	6585.70 <sup>3</sup>	3		VE
6461.17	2	4	III A	6588.02 <sup>3</sup>	2		VE
6461.86	2	8	III A	6588.82	1—	3	III A
6463.57 <sup>3</sup>	8	20	II A	6589.64 <sup>3</sup>	2	1	III
6465.23 <sup>3</sup>	2		VE	6590.94 <sup>3</sup>	2	1	III
6465.91	1	2	III A	6591.40 <sup>3</sup>	2		VE
6466.66	1—	2	III A	6592.66 <sup>3</sup>	3	10	III A
6471.71 <sup>3</sup>	2		VE	6593.67	2	3	III
6471.88	2	3	III	6595.00 <sup>3</sup>	2		VE
6473.57	2	5	III A	6596.35 <sup>3</sup>	2	6	III
6474.23	4	4	III	6601.75 <sup>3</sup>	10	20	II A
6480.25 <sup>3*</sup>	6	3	III	6609.30 <sup>3</sup>	2	3	III
6481.57 <sup>3</sup>	2	40	I A	6611.90 <sup>3</sup>	15	30	II A
6482.26 <sup>3</sup>	2		VE	6615.88 <sup>3</sup>	5	10	II A
6483.43 <sup>3</sup>	2		VE	6616.80 <sup>3</sup>	1	3	III A
6484.37 <sup>3</sup>	5	15	II A	6618.40 <sup>3</sup>	6	10	III
6485.60 <sup>3</sup>	100	100	I	6619.34 <sup>3</sup>	6	25	II A
6487.55 <sup>3</sup>	3	5	III	6625.40 <sup>3</sup>	2	4	III A
6490.15	1	3	III A	6628.71	1—	15	I A
6490.94	1	3	III A	6630.14 <sup>3</sup>	80	60	I
6492.33 <sup>3</sup>	3		VE	6635.22	1	1	III
6495.59 <sup>3</sup>	1		VE	6637.17 <sup>3</sup>	4		VE
6499.25	1—	3	III A	6637.96 <sup>3</sup>	8		VE
6500.15 <sup>3</sup>	10	15	II	6648.90	1	30	I A
6501.11 <sup>3</sup>	1	2	III A	6650.57 <sup>3</sup>	8		VE
6504.45 <sup>3</sup>	3		VE	6655.64 <sup>3</sup>	30	40	II
6504.92 <sup>3</sup>	3	10	III A	6660.16 <sup>3</sup>	3	3	III
6514.93 <sup>3</sup>	5		VE	6664.61 <sup>3</sup>	30	30	I A
6516.49d	1	4	II A	6667.54 <sup>3</sup>	1	1	III
6519.86 <sup>3</sup>	2		VE	6669.61 <sup>3</sup>	1		VE
6520.27	4	4	III	6670.37 <sup>3</sup>	4	4	III
6523.12 <sup>3</sup>	5		VE	6675.07 <sup>3</sup>	1	1	III
6525.49	1—	2	III A	6678.52 <sup>3</sup>	2		VE
6530.43	1—	5	II A	6679.75 <sup>3</sup>	4	5	III
6535.28	1	2	III A	6680.14 <sup>3</sup>	5		VE
6539.91 <sup>3</sup>	5	4	II	6682.72	1	2	III A
6540.33	1—	4	III A	6695.62 <sup>3</sup>	1	15	I A
6547.72 <sup>3</sup>	3	2	III	6698.65 <sup>3</sup>	1		VE
6549.50 <sup>3</sup>	5		VE	6699.22	1	20	I A
6550.18 <sup>3</sup>	5		VE	6709.52	1	4	III A
6553.06 <sup>3</sup>	3		VE	6712.27 <sup>3</sup>	2	2	III

TABLE I—Continued

$\lambda$	INTENSITY		CLASS	$\lambda$	INTENSITY		CLASS
	Arc	Furnace			Arc	Furnace	
6722.72 <sup>3</sup> ....	1	20	I A	6835.40.....	1—	2	III A
6723.46 <sup>3</sup> ....	1	1	III	6842.67 <sup>3</sup> ....	3	.....	VE
6724.40.....	1	3	III A	6846.73 <sup>3</sup> ....	6	.....	VE
6727.70 <sup>3</sup> ....	3	.....	VE	6849.30 <sup>3</sup> ....	2	2	III
6732.06.....	1	4	III A	6851.79.....	1	10	I A
6735.04 <sup>3</sup> ....	2	.....	VE	6852.23 <sup>3</sup> ....	4	10	III A
6737.79 <sup>3</sup> ....	5	1—	IV E	6856.96 <sup>3</sup> ....	4	6	III
6739.16 <sup>3</sup> ....	2	2	III	6873.78 <sup>3</sup> ....	2	.....	VE
6740.05 <sup>3</sup> ....	20	1—	IV E	6874.66 <sup>3</sup> ....	3	.....	VE
6742.50 <sup>3</sup> ....	6	6	III	6876.00 <sup>3</sup> ....	2	.....	VE
6743.57 <sup>3</sup> ....	1	1	III	6878.41 <sup>3</sup> ....	2	6	II A
6745.18 <sup>3</sup> ....	2	3	III	6886.86 <sup>3</sup> ....	2	1	III
6748.35 <sup>3</sup> ....	2	8	II A	6895.63.....	1—	5	II A
6749.60.....	1	8	II A	6896.65 <sup>3</sup> ....	2	2	III
6753.99.....	1	15	I A	6900.40 <sup>3</sup> ....	15	1	IV E
6763.01 <sup>3</sup> ....	4	6	III	6904.75.....	1	8	I A
6763.78 <sup>3</sup> ....	4	6	III	6905.01.....	1	6	II A
6770.94 <sup>3</sup> ....	2	12	II A	6906.03.....	3	8	II A
6775.26.....	1	2	III A	6908.89.....	1—	2	III A
6780.61 <sup>3</sup> ....	2	.....	VE	6923.86 <sup>3</sup> ....	5	30	I A
6784.70.....	1	20	I A	6926.87 <sup>3</sup> ....	2	.....	VE
6788.80.....	2	2	III	6927.99 <sup>3</sup> ....	1	4	II A
6789.10 <sup>3</sup> ....	2	.....	VE	6932.16 <sup>3</sup> ....	2	4	III A
6790.40 <sup>3</sup> ....	8	.....	VE	6940.89.....	1	4	III A
6792.28 <sup>3</sup> ....	2	8	II A	6941.39 <sup>3</sup> ....	3	.....	VE
6801.34 <sup>3</sup> ....	5	8	III	6945.02.....	1—	3	III A
6803.06 <sup>3</sup> ....	5	4	III	6951.9.....	1	2	III A
6803.07 <sup>3</sup> ....	8	.....	VE	6952.02.....	1	4	II A
6811.10.....	1—	2	III A	6964.64 <sup>3</sup> ....	3	2	III
6812.30 <sup>3</sup> ....	2	1	III	6985.26.....	5	20	I
			VE	6995.27.....	3	10	II A
6816.00 <sup>3</sup> ....	3	.....	VE	7001.71.....	2	4	III A
6822.91 <sup>3</sup> ....	2	15	I A	7004.92.....	1	3	III A
6825.35 <sup>3</sup> ....	3	3	III				

## NOTES TO TABLE I

$\lambda$		$\lambda$	
3080.061	Blend $\lambda$ 3080.940 in arc.	3254.986	Blend $Nd$ II in arc.
3092.616	Blend $Al$ in arc.	3320.421	Blend $Nd$ II in arc. May be $Gd$ .
3092.867	Blend $\lambda$ 3092.924 in arc.	3354.603	Blend $Ti$ in furnace.
3153.210	Blend in arc with $Nd$ II line of intensity 8.	3362.261	Partly $Nd$ II in arc. Furnace line may be $Gd$ .
3158.261	Blend $Nd$ II in arc.	3369.263	Blend $Nd$ II in arc.
3162.009	Close to faint $Nd$ II line.	3455.753	Blend $Nd$ II in arc.
3179.300	Blend faint $Nd$ II in arc.	3456.001	May be $Ho$ .
3215.280	Blend $Nd$ II in arc.	3464.465	Masked in arc.
3223.773	May be partly $Gd$ .	3472.372	Masked in arc.
3228.154	Blend $Nd$ II in arc.	3484.369	May be blend with $Nd$ I
3231.346	Blend $Nd$ II in arc.	3512.736	Blend $Nd$ II in arc.
3231.664	Blend $Nd$ II in arc.	3531.708	May be $Dy$ .
3249.780	Blend $Nd$ II in arc.	3582.885	Blend $Nd$ II in arc.

## NOTES TO TABLE I—Continued

$\lambda$		$\lambda$	
3585.353	Blend <i>Fe</i> in arc.	4221.137	Blend <i>Dy</i> in furnace.
3592.090	Blend <i>Nd</i> II in arc.	4256.825	Arc $\lambda$ .
3640.235	May be partly <i>Dy</i> .	4256.857	Furnace $\lambda$ .
3658.108	Furnace line may be partly <i>Ti</i> .	4305.810	Blend impurity in arc.
3664.649	Blend faint <i>Nd</i> II in arc.	4325.765	Furnace line blend <i>Gd</i> I.
3665.755	Blend faint <i>Nd</i> II to violet.	4350.73	May be blend <i>Ho</i> .
3667.564	May be impurity.	4358.699	May be partly <i>Y</i> .
3673.434	Blend in arc with $\lambda$ 3673.542.	4374.928	Probably chiefly <i>Nd</i> . Coincides very strong <i>Y</i> line.
3674.056	Blend <i>Nd</i> II to red.	4379.874	Blend faint <i>Nd</i> II in arc.
3684.131	May be <i>Gd</i> .	4452.018	Blend in arc with $\lambda$ 4451.987.
3690.080	May be impurity.	4475.574	Blend <i>Nd</i> II in arc.
3694.807	Strong in spark.	4496.409	Blend impurity in arc.
3699.766	Blend <i>Nd</i> II to violet.	4516.356	Arc $\lambda$ .
3712.128	Blend faint <i>Nd</i> II in arc.	4516.381	Furnace $\lambda$ .
3714.236	Blend $\lambda$ 3714.196 in arc.	4569.699	Weakens rapidly at low temperature.
3714.692	Close to <i>Nd</i> II in arc.	4607.378	Blend <i>Nd</i> II in arc.
3749.853	Blend <i>Nd</i> II to red.	4609.22	Blend impurity in arc.
3757.944	May be impurity.	4641.0	Blend $\lambda$ 4641.103.
3765.344	Blend <i>Nd</i> II in arc.	4644.845	Faint <i>Nd</i> II to violet.
3783.060	May be impurity.	4670.560	Blend <i>Pr</i> in furnace.
3785.106	Blend <i>Nd</i> II in arc.	4717.08	Furnace line masked by impurity.
3801.384	Close to <i>Nd</i> II in arc.	4788.34	Furnace line partly <i>Pr</i> .
3807.942	Blend band line in arc.	4827.74	Arc line partly <i>Nd</i> II.
3830.468	Strong in spark.	4828.58	May be blend <i>Nd</i> I.
3836.54	Strong in spark. Blend band in furnace.	4924.53	May be partly <i>Pr</i> .
3863.326	Blend band in furnace.	4943.90	Probably blend <i>Nd</i> I.
3863.404	Blend band in furnace.	4959.13	Blend <i>Nd</i> I to red.
3887.837	Furnace $\lambda$ .	5045.52	Partly <i>Pr</i> .
3887.87	Arc $\lambda$ .	5191.46	May be blend <i>Nd</i> I to red.
3892.06	Faint component to violet.	5239.71	Furnace $\lambda$ .
3925.495	Blend impurity in arc.	5239.75	Arc $\lambda$ .
3926.615	Blend <i>Nd</i> II in arc.	5286.72	Blend <i>Nd</i> II to violet.
3934.090	Arc $\lambda$ .	5356.92	Blend <i>Nd</i> I to violet.
3934.107	Furnace $\lambda$ .	5447.24	Furnace line double.
3937.00	Between two faint lines in arc. May be impurity.	5449.26	May be blend <i>Nd</i> II.
3937.57	Arc line partly <i>Nd</i> II.	5533.82	Violet component at low temperature.
3941.572	Blend in arc with $\lambda$ 3941.513.	5588.84	Violet component coincides <i>Sa</i> .
3942.12	Enhancement slight.	$\lambda$ measured in low-temperature furnace.	
3953.400	Blend <i>Gd</i> in furnace.	Kiess arc $\lambda$ 5620.62 given by blend with strong <i>Nd</i> II on red side.	
3963.180	Blend in arc with $\lambda$ 3963.116.	5706.20	Coincides strong <i>Sa</i> I.
3976.85	Probably blend <i>Nd</i> I.	5783.64	Double in arc. Red component is <i>Nd</i> II.
3987.434	Blend <i>Nd</i> II in arc.	May be blend with <i>Eu</i> .	
3990.017	Blend <i>Nd</i> II in arc.	Coincides faint low-temperature <i>Sa</i> .	
4007.964	May be impurity.	Coincides low-temperature <i>Sa</i> .	
4062.807	Blend impurity in arc.	Double in arc. Violet component is <i>Nd</i> II.	
4067.720	May be blend <i>Nd</i> II in arc.	5939.73	Arc line blend <i>Nd</i> II to red.
4071.455	Blend <i>Nd</i> II in arc.	6109.08	Blend <i>Pr</i> .
4105.889	Blend faint <i>Nd</i> II in arc.	6161.26	Arc line partly <i>Pr</i> .
4109.162	Blend in arc with $\lambda$ 4109.082.	6166.76	Blend in arc with $\lambda$ 6166.67. Measured in furnace.
4122.998	Close companion to violet in arc.	6174.30	Appears to belong to <i>Nd</i> , although close to low-temperature lines of <i>Sa</i> and <i>Pr</i> .
4125.048	Blend <i>Nd</i> II in arc.	6191.67	May be <i>Y</i> .
4143.04	Blend impurity in arc.	6223.38	Faint line on violet side.
4178.438	Much enhanced in spark.	6238.49	Probably blend <i>Nd</i> II.
4205.254	Arc $\lambda$ .	6263.23	Violet component is <i>Nd</i> II.
4205.271	Furnace $\lambda$ .	6270.26	Violet component is <i>Nd</i> II.
4205.78	Coincides strong <i>Sa</i> line.		
4214.225	May be blend <i>Nd</i> I.		

NOTES TO TABLE I—*Continued*

$\lambda$		$\lambda$	
6312.70	Red component blend with <i>Nd</i> II in arc.	6385.17	Double. Arc line blend <i>Nd</i> II to red.
6336.55	Faint <i>Nd</i> II to red.	6439.18	Arc line partly <i>Ca</i> .
6341.47	Wide blend in arc. Furnace line measures $\lambda$ 6341.31.	6439.75	Double in arc. Red component <i>Nd</i> II.
6362.10	Probably blend <i>Nd</i> II in arc.	6451.21	Arc line blend <i>Nd</i> II to violet.
		6480.25	Arc line partly <i>Nd</i> II.

A direct comparison of the neodymium spectrograms with a set taken for samarium under similar excitation conditions showed a considerable number of cases of close agreement in wave-length between lines in the two spectra. This circumstance was noted by Kiess<sup>7</sup> for the region  $\lambda\lambda$  5483–8545. In spectra as rich as these, a certain number of chance coincidences may be expected. Just how many is not easy to say, as the distribution of lines in a spectrum is not random. Before the discovery of the atomic-number sequence, lines common to the spectra of two rare earths were considered as probably belonging to a third rare earth occurring as an impurity in both spectra. One such possibility remains in that illinium, element 61, never definitely isolated, might be expected to show its spectrum most readily in conjunction with the spectra of the adjacent elements neodymium (60) and samarium (62). This possibility, together with the danger of rejecting true neodymium lines because fairly strong lines of the same wave-length appear in the samarium spectrum, led the writer to pay much attention to these coincident lines during the present investigation.

It soon became evident that many of these "common" lines are in fact blends of a neutral line in one spectrum with an ionized line in the other. Cases also appear in which lines are so much stronger in one spectrum than in the other, even for approximately equal excitation, that they must at present be regarded as chance coincidences. Some lines, however, are fairly strong in both spectra and show similar response to different excitations. In order to observe the relative intensities of such lines and their degree of coincidence, arc spectra of neodymium and samarium were photographed in juxtaposition, in the second order from  $\lambda$  3100 to  $\lambda$  5850, and beyond in the first order to  $\lambda$  7000. The samples used in this series were of such purity that neither showed the distinctive strong lines of the other.

<sup>7</sup> *Loc. cit.*

On the second-order plates of this set, inspection usually showed lines differing by more than  $0.03 \text{ \AA}$  to be non-coincident, thus eliminating many line-pairs which on lower-scale spectrograms appear as one line. Less than twenty lines of the same character and of comparable strength in the two spectra passed this test for coincidence in a range of spectrum for which Table I lists nearly 2300 neodymium lines. Such a proportion would seem quite within the number of chance coincidences to be expected. It is fair to say, however, that the comparison has not been extended to the weaker neutral lines in the furnace spectra of the two elements. This extension can be made when the measurement of samarium furnace lines is completed.

CARNEGIE INSTITUTION OF WASHINGTON  
MOUNT WILSON OBSERVATORY  
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A STATISTICAL STUDY OF THE ROTATIONAL  
BROADENING OF THE ABSORPTION LINE  
 $Mg\ II\ \lambda\ 4481$  IN 413 STARS OF CLASS A

By CHRISTINE WESTGATE

ABSTRACT

The axial rotation of stars, as estimated from the broadening of the  $Mg\ II$  line  $\lambda\ 4481$ , is studied statistically for 413 stars of class A. The measurements of line width were converted into their corresponding equatorial velocities in km/sec. The graph of observed frequencies of rotational velocities is compared with a theoretical curve which was constructed with regard to the probability of different inclinations of axes and with the assumption of an arbitrary distribution of real equatorial velocities among stars. The best approximation to the observed curve is obtained by assuming a distribution as in Table II.

The data accumulated for this paper consist of measurements, made on a comparator, of the width of the absorption line  $Mg\ II\ \lambda\ 4481$  on approximately 825 spectrograms of 413 A-type stars of apparent visual magnitude brighter than about 5.5. The plates were taken with the Bruce spectrograph attached to the Yerkes 40-inch refractor. The linear dispersion is 30 Å per millimeter at  $\lambda\ 4500$ . The average difference in the width of the spectral line as measured on two plates of the same star is less than 0.2 Å. The results are given in Table I.

Figure 1 illustrates the correlation of my measurements of the width of  $\lambda\ 4481$  with the rotational velocities determined by C. T. Elvey<sup>1</sup> for the same stars. The Pearson coefficient of correlation for the scatter diagram is 91 per cent. The standard error of estimate of the velocity of rotation from the measured width of  $\lambda\ 4481$  (using the line drawn in) is about 25 km per second. With the assumption that the broadening of the absorption lines is due to the Doppler effect of axial rotation, a velocity of rotation was estimated from this figure for each star and is recorded to the nearest 25 km/sec. in the last column of Table I.

The observed frequencies of the rotational velocities between 0 and 250 km/sec. (the largest obtained) are plotted in Figure 2

<sup>1</sup> *Astrophysical Journal*, 71, 221, 1930.

TABLE I

Boss	Width of $\lambda$ 4481 in Angstroms	Rotational Velocity Km/Sec.	Boss	Width of $\lambda$ 4481 in Angstroms	Rotational Velocity Km/Sec.
10.....	1.8	25	858.....	3.8	125
43.....	2.6	75	878.....	2.6	75
50.....	2.7	75	880.....	1.2	0
82.....	1.5	0	883.....	2.7	75
145.....	1.8	25	923.....	1.6	25
154.....	1.8	25	932.....	2.4	50
203.....	2.3	50	938.....	3.6	125
235.....	4.9	200	943.....	1.3	0
240.....	2.2	50	980.....	2.5	50
258.....	2.1	50	980.....	1.9	25
264.....	2.5	50	990.....	2.3	50
269.....	2.4	50	998.....	1.6	25
295.....	2.9	75	1012.....	3.8	125
300.....	3.3	100	1022.....	1.6	25
307.....	2.0	25	1022.....	2.2	50
314.....	2.7	75	1023.....	3.6	125
370.....	1.5	0	1024.....	2.0	25
371.....	2.7	75	1026.....	1.5	0
422.....	2.3	50	1029.....	3.7	125
423.....	1.8	25	1033.....	3.1	100
428.....	2.3	50	1034.....	2.9	75
441.....	2.9	75	1047.....	2.4	50
446.....	1.7	25	1054.....	2.2	50
449.....	2.2	50	1067.....	2.6	75
463.....	2.0	25	1087.....	2.4	50
466.....	2.4	50	1088.....	2.3	50
476.....	1.4	0	1089.....	2.4	50
480.....	3.6	125	1090.....	1.8	25
482.....	2.1	50	1095.....	5.6	225
508.....	2.7	75	1103.....	2.4	50
517.....	4.7	175	1114.....	2.2	50
522.....	2.6	75	1117.....	2.2	50
526.....	1.4	0	1122.....	2.3	50
534.....	1.6	25	1160.....	2.6	75
550.....	1.7	25	1104.....	1.8	25
551.....	2.4	50	1200.....	2.6	75
560.....	1.7	25	1214.....	4.5	175
597.....	2.2	50	1220.....	1.8	25
606.....	2.6	75	1226.....	1.2	0
622.....	3.1	100	1241.....	1.6	25
628.....	2.5	50	1244.....	1.8	25
664.....	1.2	0	1260.....	1.3	0
674.....	2.0	25	1268.....	3.0	100
677.....	1.8	25	1352.....	2.8	75
690.....	3.1	100	1372.....	3.6	125
700.....	3.9	150	1392.....	1.7	25
730.....	2.3	50	1411.....	2.3	50
731.....	1.2	0	1433.....	1.9	25
739.....	2.2	50	1452.....	2.2	50
757.....	2.6	75	1453.....	1.4	0
791.....	4.2	150	1457.....	1.2	0
801.....	3.2	100	1478.....	1.8	25
850.....	1.6	25	1482.....	1.5	0
			1488.....		

TABLE I—Continued

Poss	Width of $\lambda_{4481}$ in Angstroms	Rotational Velocity Km./Sec.	Boss	Width of $\lambda_{4481}$ in Angstroms	Rotational Velocity Km./Sec.
1492.....	1.6	25	2426.....	1.8	25
1501.....	1.5	0	2443.....	2.1	50
1515.....	1.6	25	2470.....	3.8	125
1516.....	3.2	100	2479.....	1.0	25
1575.....	1.9	25	2495.....	4.8	175
1581.....	4.3	150	2559.....	1.0	25
1611.....	3.2	100	2565.....	3.8	125
1647.....	3.4	100	2584.....	2.8	75
1657.....	1.5	0	2637.....	1.8	25
1668.....	3.2	100	2642.....	2.6	75
1682.....	3.6	125	2650.....	3.1	100
1690.....	1.5	0	2655.....	3.0	100
1714.....	2.5	50	2672.....	2.8	75
1716.....	3.8	125	2692.....	3.4	100
1734.....	3.9	150	2697.....	1.4	0
1738.....	3.6	125	2724.....	3.4	100
1759.....	3.4	100	2729.....	1.8	25
1763.....	3.5	125	2754.....	1.5	0
1782.....	2.4	50	2808.....	3.6	125
1853.....	3.5	125	2852.....	3.8	125
1879.....	5.5	225	2854.....	2.8	75
1883.....	3.8	125	2883.....	3.8	125
1886.....	3.9	150	2900.....	1.8	25
1928.....	1.6	25	2909.....	3.9	150
1930.....	3.9	150	2930.....	2.0	25
1950.....	2.2	50	2932.....	1.6	25
1956.....	4.4	175	2970.....	4.7	175
1968.....	1.5	0	2972.....	4.4	175
1974.....	2.4	50	2974.....	1.6	25
1977.....	3.8	125	2982.....	4.7	175
1979 (br).....	1.4	0	2987.....	1.8	25
1979 (ft).....	1.7	25	2990.....	1.9	25
2010.....	2.3	50	3005.....	2.5	50
2035.....	2.2	50	3023.....	4.1	150
2045.....	4.3	150	3088.....	3.4	100
2078.....	3.6	125	3097.....	2.3	50
2088.....	2.0	25	3101.....	3.9	150
2091.....	2.3	50	3117.....	3.8	125
2120.....	4.2	150	3123.....	1.2	0
2138.....	3.9	150	3126.....	2.4	50
2145.....	4.1	150	3135.....	2.3	50
2185.....	2.7	75	3139.....	2.0	25
2237.....	3.3	100	3143.....	2.6	75
2240.....	1.8	25	3182.....	2.3	50
2264.....	2.1	50	3190.....	4.2	150
2295.....	5.5	225	3192.....	4.7	175
2327.....	2.8	75	3207.....	5.0	200
2357.....	4.1	150	3210.....	1.9	25
2361.....	4.3	150	3231.....	1.6	25
2398.....	3.7	125	3244.....	2.2	50
2404.....	4.3	150	3250.....	3.3	100
2407.....	2.3	50	3260.....	2.3	50
2424.....	4.9	200	3277.....	2.8	75

TABLE I—Continued

Boss	Width of $\lambda_{4481}$ in Angstroms	Rotational Velocity Km./Sec.	Boss	Width of $\lambda_{4481}$ in Angstroms	Rotational Velocity Km./Sec.
3283.....	2.1	50	4080.....	1.6	25
3309.....	4.0	150	4081.....	3.4	100
3310.....	3.0	100	4113.....	4.1	150
3323.....	2.6	75	4119.....	1.9	25
3363.....	1.6	25	4120.....	5.1	200
3409.....	1.7	25	4182.....	2.4	50
3450.....	3.2	100	4184.....	4.0	150
3474.....	2.2	50	4189.....	2.3	50
3475.....	2.0	25	4203.....	3.8	125
3480.....	5.1	200	4220.....	5.1	200
3494.....	2.8	75	4229.....	2.8	75
3506.....	1.6	25	4232.....	4.9	200
3508.....	5.0	200	4280.....	2.1	50
3509.....	3.8	125	4284.....	1.9	25
3512.....	3.8	125	4285.....	1.9	25
3530.....	4.1	150	4328.....	2.2	50
3600.....	2.3	50	4332.....	1.5	0
3612.....	4.1	150	4346.....	3.7	125
3626.....	1.6	25	4358.....	2.6	75
3639.....	3.5	125	4360.....	1.3	0
3654.....	2.9	75	4382.....	3.0	100
3666.....	3.8	125	4391.....	3.3	100
3669.....	1.8	25	4395.....	2.7	75
3672.....	2.3	50	4401.....	1.3	0
3692.....	3.5	125	4402.....	3.0	100
3697.....	4.2	150	4419.....	2.0	25
3705.....	1.9	25	H.D. 157778.....	3.8	125
3743.....	3.6	125	4428.....	4.1	150
3744.....	3.0	100	4458.....	2.7	75
3749.....	1.4	0	4460.....	2.1	50
3750.....	2.6	75	4459.....	4.8	175
3752.....	4.5	175	4462.....	2.1	50
3779.....	1.6	25	4500.....	4.6	175
3787.....	2.5	50	4511.....	3.5	125
3825.....	2.9	75	4552.....	6.1	250
3853.....	2.2	50	4581.....	2.6	75
3866.....	2.4	50	4584.....	3.0	100
3883.....	3.1	100	4587.....	3.8	125
3911.....	4.3	150	4586.....	4.9	200
3928.....	4.9	200	4591.....	4.0	150
3939.....	3.4	100	4592.....	2.1	50
3943.....	2.0	25	4644.....	4.7	175
3949.....	5.2	200	4661.....	2.6	75
3961.....	3.3	100	4667.....	3.6	125
3994.....	2.7	75	4670.....	2.8	75
3998.....	3.0	100	4671.....	4.0	150
4004.....	2.6	75	4674.....	5.2	200
4009.....	3.9	150	4722.....	1.7	25
4016.....	3.1	1000	4745.....	1.9	25
4022.....	2.1	50	4747.....	4.4	175
4026.....	1.6	25	4749.....	5.1	200
4035.....	5.1	200	4752.....	1.6	25
4072.....	4.0	150	4754.....	3.9	150

TABLE I—Continued

Boss	Width of $\lambda$ 4481 in Angstroms	Rotational Velocity Km/Sec.	Boss	Width of $\lambda$ 4481 in Angstroms	Rotational Velocity Km/Sec.
4761.....	3.0	100	5427.....	3.4	100
4775.....	3.2	100	5460.....	1.8	25
4788.....	2.2	50	5480.....	5.2	200
4802.....	4.0	150	5491.....	2.5	50
4803.....	4.7	175	5515.....	2.8	75
4818.....	2.4	50	5517.....	1.9	25
4824.....	3.0	100	5551.....	4.5	175
4841.....	1.9	25	5553.....	4.2	150
4846.....	3.8	125	5596.....	4.3	150
4850.....	5.7	225	5600.....	3.2	100
4858.....	4.7	175	5605.....	3.4	100
4867.....	3.9	150	5608.....	1.8	25
4869.....	5.1	200	5617.....	2.2	50
4899.....	5.4	225	5669.....	2.9	75
4902.....	2.6	75	5671.....	2.6	75
4905.....	3.8	125	5679.....	3.1	100
4914.....	3.5	125	5703.....	4.7	175
4948.....	1.3	0	5713.....	4.6	175
4988.....	5.0	200	5734.....	2.8	75
5002.....	2.6	75	5761.....	2.5	50
5022.....	2.5	50	5784.....	5.8	250
5048.....	4.7	175	5806.....	4.4	175
5062.....	5.0	200	5813.....	3.7	125
5086.....	1.8	25	5818.....	2.6	75
5092.....	3.7	125	5837.....	3.0	100
5099.....	2.1	50	5858.....	1.4	0
5101.....	2.8	75	5904.....	2.5	50
5105.....	3.8	125	5910.....	2.7	75
5132.....	1.6	25	5936.....	4.3	150
5139.....	2.7	75	5944.....	3.6	125
5171.....	2.3	50	5973.....	5.5	225
5182.....	3.8	125	5997.....	4.0	150
5185.....	4.5	175	6005.....	4.4	175
5188.....	2.8	75	6010.....	3.8	125
5191.....	4.6	175	6023.....	3.0	100
5214.....	1.6	25	6031.....	2.1	50
5249.....	3.5	125	6063.....	3.8	125
5270.....	2.6	75	6072.....	5.0	200
5275.....	2.4	50	6076.....	3.0	100
5282.....	3.2	100	6080.....	4.1	150
5301.....	2.3	50	6084.....	2.3	50
5320.....	1.7	25	6087.....	4.4	175
5323.....	2.4	50	6099.....	3.3	100
5337.....	3.6	125	6108.....	5.2	200
5343.....	5.2	200	6119.....	2.6	75
5365.....	3.2	100	6128.....	4.4	175
5393.....	5.4	225	6179.....	5.2	200
5417.....	2.4	50			

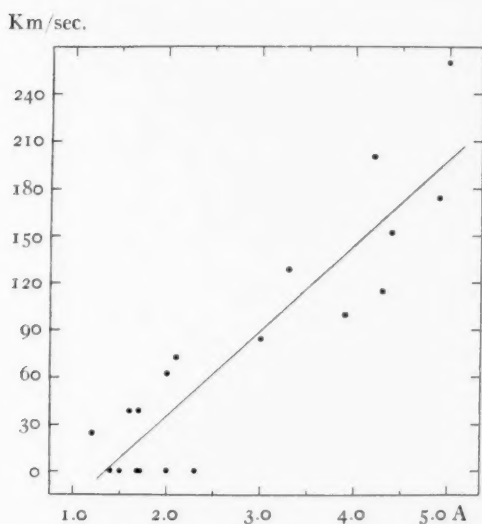


FIG. 1.—Comparison of Elvey's determinations of rotational velocities with author's measurements of the widths of  $\lambda 4481$  for the same stars.

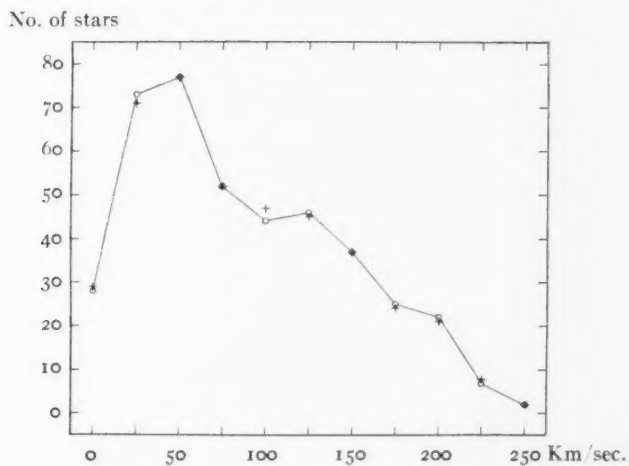


FIG. 2.—Frequency diagram. Continuous line, observed; crosses, computed ordinates.

(continuous line). As was done in a previous case for a number of B stars,<sup>2</sup> a frequency-curve was computed on the basis of the proba-

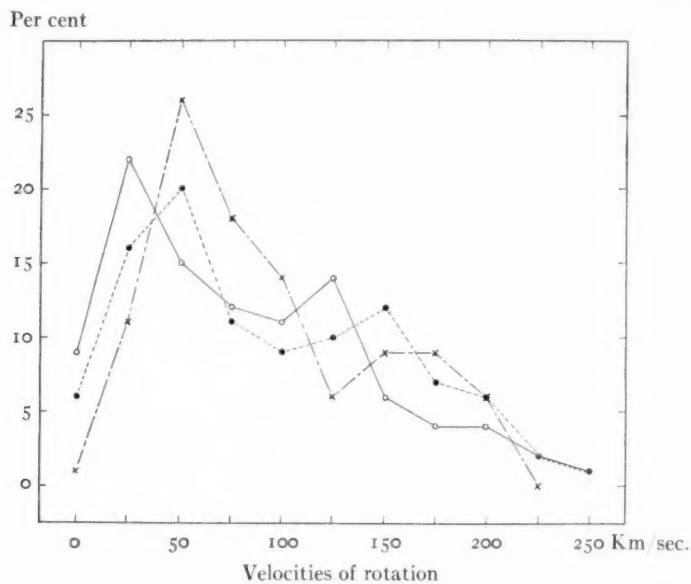


FIG. 3.—Frequency diagram. Circles are for stars of type A<sub>0</sub>; dots, for A<sub>2</sub> and A<sub>3</sub>; and crosses for A<sub>5</sub>.

TABLE II  
ASSUMED DISTRIBUTION OF EQUATORIAL VELOCITIES  
AMONG A-TYPE STARS

Km/Sec.	Per Cent of Stars	Km/Sec.	Per Cent of Stars
0.....	3	150.....	12
25.....	13	175.....	8
50.....	17	200.....	7
75.....	11	225.....	4
100.....	10	250.....	1
125.....	14		

bility of different inclinations of axes among stars, and with the assumption of an arbitrary distribution of stellar equatorial velocities. Table II gives those assumed distributions which best repro-

<sup>2</sup> *Ibid.*, 77, 141, 1933.

duce the observed frequencies. The crosses in Figure 2 are the computed ordinates. Almost 80 per cent of the A-type stars studied are indicated as having real axial rotations quite evenly divided among velocities from 25 to 150 km/sec.

Although the averages of the observed widths of the absorption line  $Mg\ II\ \lambda\ 4481$  for subdivisions A0, A2, A3, and A5 (Henry Draper classification) remain practically constant (3.0 Å), there is an indication that stars of later type tend to have slightly higher velocities. The data, as arranged for such a comparison, are given graphically in Figure 3.

YERKES OBSERVATORY  
March 1933

## NOTE ON THE SPECTRA OF 17 LEPORIS AND 7 $\epsilon$ AURIGAE

By J. A. HYNEK

### ABSTRACT

The intensity gradients of absorption lines in the spectra of 17 Leporis (A0) and 7  $\epsilon$  Aurigae (F5) have been examined. 17 Leporis shows a steeper gradient than  $\epsilon$  Aurigae does; faint lines become unmeasurable in 17 Leporis while the corresponding lines in  $\epsilon$  Aurigae are still well defined, but strong lines are as strong as, or stronger than, those in  $\epsilon$  Aurigae. The hydrogen lines are not comparable, being much stronger and broader in 17 Leporis.

Six  $Ti\ II$  multiplets were examined in the two stars. The gradients within each multiplet indicate the same effect that is shown by the entire element in the two stars. Further confirmation is given of the square-root law of absorption intensities.

The abnormal intensity gradient in the absorption spectrum of 17 Leporis was first noted by O. Struve<sup>1</sup> in 1931. No other star examined at the Yerkes Observatory exhibits this property. To determine quantitatively the magnitude of this effect by comparison with another star, a spectrophotometric investigation of 17 Leporis and 7  $\epsilon$  Aurigae was made. The intensity gradient of the lines as a whole and also in individual multiplets was examined.

Nine plates each of the two stars were studied. The spectrograms of 17 Leporis chosen were those not exhibiting the abnormal doubling of lines which occurs at certain times in this spectrum variable. All plates were taken with the Bruce spectrograph on the 40-inch Yerkes telescope and have a linear dispersion of 30 Å per millimeter at  $\lambda\ 4500$ . The microphotograms were made with the Moll microphotometer at Ryerson Physical Laboratory. Five of the best plates of 17 Leporis were also measured with the Yerkes microphotometer to effect a direct comparison of the two instruments and to minimize instrumental error. The two microphotometers differ mainly in speed, the Moll requiring but one-tenth of the time that is necessary for the Yerkes photometer to produce a microphotogram.

The results are set forth in Table I. For each line listed in the first column there is given its intensity in 7  $\epsilon$  Aurigae and in 17 Leporis and the probable error of the mean of the intensity measurements of

<sup>1</sup> *Astrophysical Journal*, 76, 85, 1932.

TABLE I

$\lambda$	7 $\epsilon$ AURIGAE		17 LEPORIS					
	Moll		Moll		Yerkes		Adopted	
	Int.	P.E.	Int.	P.E.	Int.	P.E.	Int.	P.E.
3982.10	1.35	$\pm .00$						
3987.60	.49	.04						
3991.17	.45	.02						
3997.16	.58	.02						
3999.02	.56	.03						
4002.06								
4002.85	.71	.06						
4005.48	1.16	.04						
4012.37	1.41	.05	tr.		tr.		tr.	
4014.47	.36	.12						
4018.39	.25							
4021.96	.25							
4023.31	.72	.05						
4024.98	1.46	.04	tr.		tr.			
4028.29	1.22	.06					tr.	
4029.84	.68	.06						
4032.96	.57	.07						
4034.44	.25	.07						
4035.64	.69	.04						
4036.86	.22	.06						
4038.12	.17	.01						
4039.71	.17	.01						
4041.20	.14							
4044.08	.22	.04						
4045.78	1.21	.10	tr.		tr.		tr.	
4048.70	.53	.05						
4050.51	.20	.03						
4051.95	.50	.03						
4053.84	1.07	.07	tr.		tr.		tr.	
4056.25	.25	.04						
4057.53	.14							
4063.57	1.17	.06	tr.		tr.		tr.	
4067.00	.65	.04						
4071.75	1.18	.08	tr.		tr.		tr.	
4077.70	1.84	.10	tr.		tr.		tr.	
4101.77	4.9	.16	14.9	.67			14.9	.67
4107.48	.10							
4109.75	.59	.05						
4113.26	.26	.03						
4118.57	.36	.02						
4122.63	.92	.02						
4124.80	.36	.03						
4128.25	1.50	.05	tr.		tr.		tr.	
4130.70	.35	.04						
4132.22	.65	.05	tr.		tr.		tr.	
4133.92	.10							
4134.67	.14							
4137.03	.20	$\pm .04$						
4138.35	.14							
4140.10	.14							

TABLE I—Continued

$\lambda$	7 $\epsilon$ AURIGAE		17 LEPORIS					
	Moll		Moll		Yerkes		Adopted	
	Int.	P.E.	Int.	P.E.	Int.	P.E.	Int.	P.E.
4143.73.....	.68	$\pm .04$	tr.		tr.		tr.	
4145.70.....	.26	.03						
4147.73.....	.10							
4149.17.....	.51	.03						
4150.89.....	.17	.03						
4152.27.....	.10							
4154.38.....	.30	.03						
4156.34.....	.32	.02						
4161.37.....	.97	.03	tr.		tr.		tr.	
4163.59.....	1.05	.06	tr.		tr.		tr.	
4167.29.....	.10	.01						
4171.89.....	1.30	.06	bl.,		bl., 1.34	.13	bl., 1.31	.07
4173.57.....	2.04	.13	1.28	.07				
4175.62.....	.10							
4177.60.....	1.36	.11	bl.,		bl., 1.18	.14	bl., 1.28	.08
4178.98.....	1.85	.06	1.38	.08				
4181.74.....	.14	.01						
4183.54.....	.43	.01	tr.		tr.		tr.	
4187.41*	.47	.03						
4190.37.....	.26	.005						
4195.35.....	.26	.04						
4198.60.....	.40	.05						
4202.17.....	.68	.03						
4205.16.....	.65	.03						
4207.22.....	.10		tr.		tr.		tr.	
4209.00.....	.33	.03						
4211.93.....	.20	.04						
4215.56.....	1.29	.04						
4219.64.....	.14							
4222.27.....	.14							
4224.98.....	.48	.04						
4227.02*	1.18	.09	.44	.02	.48	.07	.46	.04
4233.19.....	2.04	.12	2.24	.07	2.22	.17	2.23	.09
4235.97.....	.39	.02						
4238.70.....	.28	.02						
4242.40.....	.80	.04			.50	.04	.50	.04
4246.84.....	1.51	.05	1.70	.08	1.73	.11	1.71	.07
4250.56.....	.59	.03						
4252.62.....	.41	.04						
4254.47.....	.39	.03						
4258.17.....	.78	.05						
4260.52.....	.48	.04						
4261.98.....	.62	.05						
4263.82.....	.10							
4269.29.....	.30	.04						
4271.70.....	1.01	.06	tr.		tr.		tr.	
4273.39.....	.68	$\pm .06$						

\* The wave-lengths listed are identical with those measured and identified in  $\epsilon$  Aurigae (*Publications of the Yerkes Observatory*, 7, Part II, 1932); lines marked by \* indicate that the measured wave-length in 17 Leporis is not identical.

TABLE I—Continued

$\lambda$	7 $\epsilon$ AURIGAE		17 LEPORIS					
	Moll		Moll		Yerkes		Adopted	
	Int.	P.E.	Int.	P.E.	Int.	P.E.	Int.	P.E.
4275.41	.60	$\pm$ .04						
4278.16	.44	.04						
4282.53	.24	.02						
4284.22	.51	.06						
4287.02	.77	.08						
4290.19	1.53	.05	.89	.05	.85	.06	.87	.04
4292.21	.14							
4294.18	1.53	.06	.95	.06	.97	.07	.96	.05
4296.50	.02	.05	.28	.03	.22	.05	.25	.03
4300.02	1.76	.05	1.72	.07	1.63	.05	1.67	.04
4302.04	1.53	.11	.82	.03			.82	.03
4303.17	1.40	.09			1.07	.11		
4305.72	.26	.03						
4307.88	1.31	.06	.75	.06	.77	.04	.76	.04
4309.66	.22	.02						
4312.89	1.16	.03	.80	.04			.80	.04
4314.68	2.15	.11	.95	.06	1.81	.16	.95	.06
4316.04	.42	.03						
4320.85	1.48	.09	.55	.04	.50	.03	.53	.03
4325.36	1.76	.12			.58	.06	.58	.06
4330.50	.89	.05						
4337.87	2.89	.07						
4340.59	4.33	.22	12.6	.95	16.7	.54	14.6	.54
4344.28	1.08	.06						
4351.74	1.93	.11	2.44	.09	2.32	.04	2.38	.05
4354.64	.22	.03						
4359.67	.10							
4362.08	.14	.03						
4365.25	.10							
4367.68	.75	.06						
4369.47	.47	.06						
4374.73	1.83	.13			.37	.03	.37	.03
4379.86	.24	.11						
4383.73	1.40	.16			1.45	.09	1.45	.09
4385.25	1.62	.18						
4386.87	.33	.04						
4390.99	.56	.04						
4394.37*	2.67	.09	1.07	.06	1.73	.08	1.85	.05
4398.22*	1.93	.10	.62	.04	.50	.05	.56	.03
4404.78	.63	.05						
4407.75	.20	.04						
4409.40	.45	.06						
4411.19								
4411.92	.57	.06						
4415.43	1.00	.10						
4417.53	2.50	.11	1.03	.07	1.04	.07	1.03	.05
4422.14	.58	.05						
4441.82	.55							
4443.94	2.17	.12	1.85	.06	1.65	.12	1.75	.07
4450.54	1.22	$\pm$ .02	.40	.04	.30	.03	.35	.03

TABLE I—Continued

$\lambda$	7 $\epsilon$ AURIGAE		17 LEPORIS					
	Moll		Moll		Verkes		Adopted	
	Int.	P.E.	Int.	P.E.	Int.	P.E.	Int.	P.E.
4454.90	.35	$\pm .01$						
4459.05	.24							
4461.45	.20	.00						
4464.40	.51	.03			tr.		tr.	
4468.60	1.81	.13	1.35	.06	1.40	.13	1.37	.07
4470.90	.37	.04						
4472.99	.33	.03						
4481.26	1.46	.00	.88	.04	.96	.08	.92	.05
4488.88	1.22	.05			.43		.43	
4491.34	.91	.05			.61	.06	.61	.06
4501.26	1.44	.10	1.27	.07	1.16	.08	1.22	.05
4508.33	1.25	.06	1.03	.05	.86	.07	.96	.04
4515.35	1.02	.06	.88	.07	.82	.05	.85	.04
4520.24	1.02	.12			.75	.03	.75	.03
4522.67	1.13	.06	1.25	.06	1.26	.10	1.25	.06
4529.19	.71	.04	tr.		tr.		tr.	
4534.00	1.43	.08	1.79	.08	1.48	.14	1.63	.08
4541.47	.75	.05			.35	.01	.35	.01
4544.19								
4544.95	.36							
4549.50	1.70	.13	2.60	.11	1.93	.14	2.27	.09
4552.28	.22							
4554.20*	1.68	.13	1.04	.05	1.11	.07	1.07	.04
4558.62	.90	.08	.86	.05	.75	.08	.81	.05
4563.77	1.40	.10	.91	.06	1.08	.13	1.00	.07
4571.97	1.25	.07	1.31	.08	1.16	.07	1.24	.05
4576.34	.73	.06			.36		.18	
4579.98*	.59	.06						
4583.61*	1.99	.11	2.12	.07	1.72	.15	1.92	.08
4588.21	.76	.05			.61	.08	.61	.08
4590.02	.75	.05			tr.		tr.	
4592.12	.73	.06						
4616.61	.53	.04						
4618.91	.88	.06	tr.		tr.		tr.	
4620.63	.65	.03						
4629.38	1.20	.08	.91	.06	.92		.91	.06
4634.19	1.07	.08						
4657.10	.83	.05						
4663.59	.45	.05						
4666.82	.90	.08						
4670.39	.71	.05						
4731.47	.70	.05						
4764.03	.67	.04						
4780.04	.68	.04						
4805.13	.77	.06						
4824.15	.91	.04			tr.		tr.	
4848.30	.86	.03						
4861.33	4.74	$\pm .25$	14.3	.75			14.3	.75

each line. Three intensities are listed for each line of 17 Leporis: the mean of the Moll measurements, the mean of the Yerkes measurements, and the adopted intensity, which is the mean of the two. Probable errors are given for each measurement. A comparison of the intensities measured with the Yerkes and the Ryerson instruments shows that while the scatter for individual plates is high, the means of such measures compare favorably. The probable errors are also of the same order but are somewhat higher for the slower of the two instruments. The scatter in the individual measures can be attributed mainly to the natural graininess of the spectrograms (it being difficult to distinguish faint lines from the dips in the tracing due to grain clusters) and to errors of judgment in drawing in the continuous spectrum and in measuring the widths and the depths of the line contours.

Table I represents all measurable lines in each spectrum except strong blends. In some cases the combined intensities of two or more neighboring lines have been given. The intensities are tabulated in units of  $(\Delta\lambda/\lambda) \times 10^{-8}$ , the ratio of effective breadth to the wavelength, and are thus proportional to the square root of the number of absorbing atoms. Instead of plotting the contour of each line and then performing a planimeter integration, the base and the depth of the line at  $\lambda_0$  were measured, and the area of a triangle of those dimensions was taken to be the area of the contour.

The lines listed are those measured for  $\epsilon$  Aurigae, which has many more blends than has 17 Leporis. The intensities listed for 17 Leporis occasionally do not apply to the exact wave-length listed for  $\epsilon$  Aurigae, but for one of the blends, of which only one line may be present in the spectrum of 17 Leporis.

An examination of the table reveals the fact—peculiar, as far as is known, to 17 Leporis—that while the strong lines are as strong as, or stronger than, the corresponding lines in  $\epsilon$  Aurigae, the weak lines are decidedly weaker, becoming unmeasurable while those of  $\epsilon$  Aurigae are still very well defined. No theoretical explanation has been brought forth.

In Figure 1 the absorption intensities of 17 Leporis are plotted, line for line, against those of  $\epsilon$  Aurigae as abscissae, using those lines

of  $Ti II$  and  $Fe II$  which are reasonably free from blends. The curve indicates the nature of the effect first noted by Struve. The wavelengths of 77 lines in the spectrum of 17 Leporis were measured by Struve.<sup>2</sup> They comprise 30 lines of  $Ti II$ , 19 of  $Fe II$ , 9 of  $Fe I$ , 6 of  $Sc II$ , 5 of  $Cr II$ , 3 of  $H$ , and 1 each of  $Zr II$ ,  $Ca I$ ,  $Sr II$ ,  $Y II$ , and  $Mg II$ . The spectrum of  $\epsilon$  Aurigae, on the other hand, contains 326 lines. While 17 Leporis is of spectral class A0,  $\epsilon$  Aurigae is of spectral class F5.

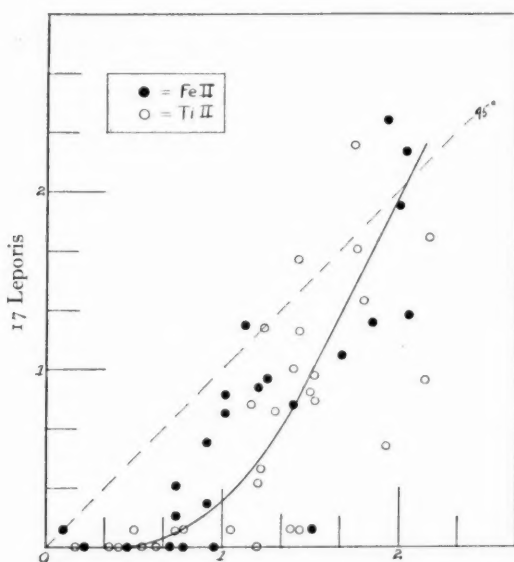


FIG. 1.— $\epsilon$  Aurigae

Theoretically, it would be expected that when the lines of an element in one star are compared in this manner with the same lines in another star, the plotted points would lie on a straight line passing through the origin, the slope of the line being a function of the difference in temperature of the two stars. The curve in Figure 1, however, apparently does not have a constant slope. The diagram shows clearly that near the origin we find many faint lines distinctly measurable in  $\epsilon$  Aurigae but totally absent in 17 Leporis. It is not until we approach intensity 1 in  $\epsilon$  Aurigae (units as above,  $[\Delta\lambda/\lambda] \times 10^{-8}$ )

<sup>2</sup> *Ibid.*

or the midpoint in the total intensity range, that the corresponding lines become measurable in 17 Leporis. The gradient in 17 Leporis is very steep.

Every line tabulated for 17 Leporis in Table I was observed visually by Struve. Some, however, were so faint that on the tracings their contours could not be distinguished from the dips of the grain clusters. Other faint lines, though visible as traces on the microphotograms, were too weak to be measured. Both types are entered in the table as "tr." and in Figure 1 are arbitrarily assigned the intensity 0.1. Lines unobserved in 17 Leporis have been assigned intensity 0, but are too numerous to record in the table and diagram. A few of these 0-intensity lines are shown in Figure 1, to demonstrate how strong a line may be in  $\epsilon$  Aurigae and still be unobservable in 17 Leporis. This in itself, of course, would be of no importance, were it not for the fact that there are lines of the same element which are stronger in 17 Leporis than in  $\epsilon$  Aurigae.

The hydrogen lines are of a different order of intensity in the two stars but are in keeping with the trend of Figure 1; they are very much stronger and broader in 17 Leporis than in  $\epsilon$  Aurigae. The intensities of  $H\delta$ ,  $H\gamma$ , and  $H\beta$  in 17 Leporis are 14.9, 14.6, and 14.3, respectively, while in  $\epsilon$  Aurigae they are 4.9, 4.3, and 4.7, respectively.

It might be supposed that the variability of the spectrum of 17 Leporis would in some way account for the effect noted above. This does not seem to be the case, for the effect has not been noticed in other stars having variable spectra; e.g.,  $\nu$  Sagittarii and H.D. 45910. A cursory examination of Plaskett's reproductions<sup>3</sup> of the spectra of these two stars shows that the effect, if it exists, is certainly not as pronounced as it is in the case of 17 Leporis.

The emission intensities of six  $Ti II$  multiplets were calculated with the usual formulae and compared with the absorption intensities of both 17 Leporis and  $\epsilon$  Aurigae. Table II contains the results. The first column has the multiplet number according to Russell,<sup>4</sup> and the wave-lengths; the second column the line designations; the third column the calculated intensities; the fourth, the square

<sup>3</sup> *Publications of the Dominion Astrophysical Observatory*, 4, No. 1, 1927.

<sup>4</sup> *Astrophysical Journal*, 66, 283, 1927.

roots of the calculated intensities; the fifth, the intensities of 17 Leporis; the sixth, the intensities in  $\epsilon$  Aurigae; and the seventh, the ratios of the intensity in 17 Leporis to that in  $\epsilon$  Aurigae. Columns

TABLE II  
MULTIPLY COMPARISONS

$\lambda$	Desig.	Calc. Int.	$\sqrt{C.I.}$	17 Lep.	7 Aur.	17 Lep. 7 Aur.
No. 19:						
4589.96.....	$a^2P_{3/2} - z^2D_{3/2}^o$	1.0	1.0	tr.	1.0	tr.
4593.77.....	$a^2P_{1/2} - z^2D_{3/2}^o$	5.0	2.2	1.0	1.9	.71
4533.97.....	$a^2P_{3/2} - z^2D_{5/2}^o$	9.0	3.0	1.6	1.9	1.14
No. 22:						
4571.98.....	$a^2H_{9/2} - z^2G_{7/2}^o$	44.0	6.6	1.0	1.8	1.00
4549.64.....	$a^2H_{11/2} - z^2G_{9/2}^o$	54.0	7.3	1.8	2.4	1.63
4529.46.....	$a^2H_{9/2} - z^2G_{9/2}^o$	1.0	1.0	tr.	1.0	tr.
No. 28:						
4450.49.....	$a^2D_{5/2} - z^2F_{5/2}^o$	1.0	1.0	1.0	1.0	.29
4443.80.....	$a^2D_{3/2} - z^2F_{5/2}^o$	14.0	3.7	5.0	1.8	.81
No. 32:						
4386.84.....	$b^2F_{5/2} - y^2G_{7/2}^o$	1.0	1.0	0	1.0	0
4367.67.....	$b^2F_{7/2} - y^2G_{9/2}^o$	1.25	1.1	0	2.3	0
No. 30:						
4411.94.....	$b^4P_{1/2} - z^4D_{1/2}^o$	5.0	2.2	0	1.3	0
4409.53.....	$b^4P_{3/2} - z^4D_{1/2}^o$	1.0	1.0	0	1.0	0
4400.23.....	$b^4P_{5/2} - z^4D_{5/2}^o$	5.4	2.3	0	1.0	0
4398.31.....	$b^4P_{1/2} - z^4D_{3/2}^o$	5.0	2.2	1.0	4.3	.29
4395.86.....	$b^4P_{5/2} - z^4D_{7/2}^o$	24.0	4.9	3.3	5.9	.70
4391.02.....	$b^4P_{3/2} - z^4D_{5/2}^o$	12.6	3.5	0	1.3	0
No. 36:						
4330.71.....	$a^4P_{5/2} - z^4D_{3/2}^o$	1.0	1.0	0	1.0	0
4320.95.....	$a^4P_{3/2} - z^4D_{1/2}^o$	1.7	1.3	1.0	1.7	.33
4314.98.....	$a^4P_{1/2} - z^4D_{1/2}^o$	8.3	2.9	3.5	2.4	.84
4312.88.....	$a^4P_{5/2} - z^4D_{5/2}^o$	9.0	3.0	3.5	2.4	.84
4307.89.....	$a^4P_{3/2} - z^4D_{3/2}^o$	10.7	3.3	1.5	1.9	.46
4301.93.....	$a^4P_{1/2} - z^4D_{3/2}^o$	8.3	2.9	2.1	1.7	.69
4300.05.....	$a^4P_{5/2} - z^4D_{7/2}^o$	40.0	6.3	3.2	2.0	.95
4290.23.....	$a^4P_{3/2} - z^4D_{5/2}^o$	21.0	4.6	1.7	1.7	.57

3, 4, 5, and 6 have all been reduced to relative intensities within the multiplet, the weakest line (except those denoted as traces) being assigned intensity 1. The ratios in column 7 are, however, those of the measured intensities in Table I.

According to Struve and Elvey,<sup>5</sup> the absorption intensity of a line

<sup>5</sup> *Ibid.*, 72, 267, 1930.

is proportional to the square root of the laboratory emission intensity. Column 4 should then be directly comparable with columns 5 and 6. The scatter is great, and yet it is obvious that columns 5 and 6 compare more favorably with column 4 than with column 3, the direct calculated emission intensity. This would tend to confirm the results by Struve and Elvey.

Column 7 of the same table shows what would be expected from Figure 1. The ratios increase greatly as the calculated intensities of the lines increase, showing that even within individual multiplets the gradients in 17 Leporis are definitely steeper than in  $\epsilon$  Aurigae.

Grateful acknowledgment is made to Dr. Struve for the suggestion of the problem, and to Drs. Gale and Monk, of Ryerson Physical Laboratory, for the use of the Moll microphotometer.

YERKES OBSERVATORY

February 1933

# NOTES

## NOTE ON THE RADIAL VELOCITY OF 27 CANIS MAJORIS

### ABSTRACT

Radial velocities obtained in 1931, 1932, and 1933 are given, indicating a decrease since 1931.

The radial velocities of 27 Canis Majoris obtained from seven recent spectrograms are given in Table I. They are shown graphically

TABLE I

Date	G.C.T.	Observers	Quality	Velocity Km/Sec.
1931 Dec	2.41	$\sigma$ , S	g	+138
1932 Dec	22.34	C, S	p	94
1932 Dec	26.36	W, S	p	38
1933 Jan	1.32	C, S	g	65
1933 Jan	4.31	C, W, S	g	57
1933 Feb	15.12	C, S	g	41
1933 Apr	15.08	W, $\sigma$ , S	p	+ 5

$\sigma$ =O. Struve; C=C.C. Crump; S=F.R. Sullivan; W=C. Westgate; g=good; p=poor.

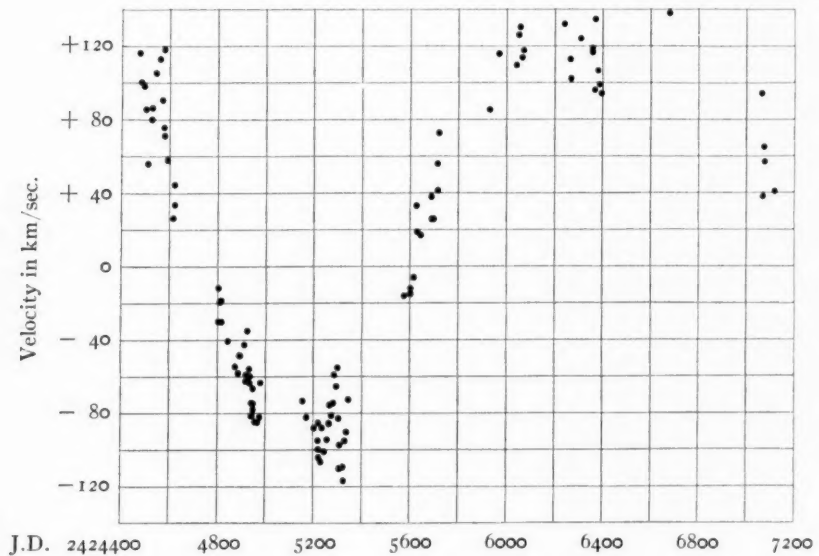


FIG. 1.—Velocity-curve of 27 Canis Majoris

in Figure 1, together with results obtained at this observatory<sup>1</sup> since 1925. The velocity has definitely decreased since 1931 and it seems that the star is now in the same stage in which it was in the spring of 1926. An attempt to derive a more accurate period with the help of observations taken between 1907 and 1916 was unsuccessful.<sup>2</sup>

J. L. HALPERN

YERKES OBSERVATORY

April 1933

### NOTE CONCERNING THE STATISTICAL RELATION BETWEEN COLOR EXCESSES AND INTENSITIES OF THE INTERSTELLAR CALCIUM LINE K

#### ABSTRACT

The presence of a weak correlation between color excess and the intensity of the interstellar calcium line K is confirmed. If this is interpreted as indirectly an effect of distance, a space reddening of 0.34 mag. per 1000 parsecs may be derived.

Struve,<sup>3</sup> Greaves, Davidson, and Martin,<sup>4</sup> Gerasimovič,<sup>5</sup> and Becker<sup>6</sup> have all found some reddening of starlight with increasing intensities of interstellar  $Ca^+$ . On the other hand, outstanding contradictory examples have been pointed out by Struve<sup>7</sup> and by Gerasimovic.<sup>5</sup> Elvey also found no correlation in a particular region, that of Cepheus.<sup>8</sup>

In this paper the presence of a statistical relation between color excesses and interstellar  $Ca^+$  intensities will be further tested with slightly more extensive material than has been hitherto available.

1. Color excesses determined with photo-electric photometers by Bottlinger and by Elvey were incorporated. Observations of a total

<sup>1</sup> *Astrophysical Journal*, **65**, 273, 1927; **66**, 113, 1927; **68**, 109, 1928; **73**, 301, 1931; **75**, 158, 1932.

<sup>2</sup> The last measure, April 15, is not shown in Fig. 1.

<sup>3</sup> *Popular Astronomy*, **34**, 1, 1926; *Astronomische Nachrichten*, No. 5447, 377, 1926; *Naturwissenschaften*, **17**, 717, 1929.

<sup>4</sup> *Monthly Notices of the Royal Astronomical Society*, **89**, 125, 1928.

<sup>5</sup> *Harvard College Observatory Bulletin*, No. 864, 14, 1929; *Harvard College Observatory Circular*, No. 339, 1929.

<sup>6</sup> *Zeitschrift für Astrophysik*, **5**, Heft 2, 101, 1932.

<sup>7</sup> *Naturwissenschaften*, **17**, 718, 1929.

<sup>8</sup> *Astrophysical Journal*, **75**, 354, 1932.

of 131 stars were made up of 55 by Bottlinger,<sup>9</sup> 71 by Elvey,<sup>10</sup> and 38 by Elvey and Mehlin.<sup>8</sup> The color excesses of the three systems were arbitrarily converted into one, that of Elvey.

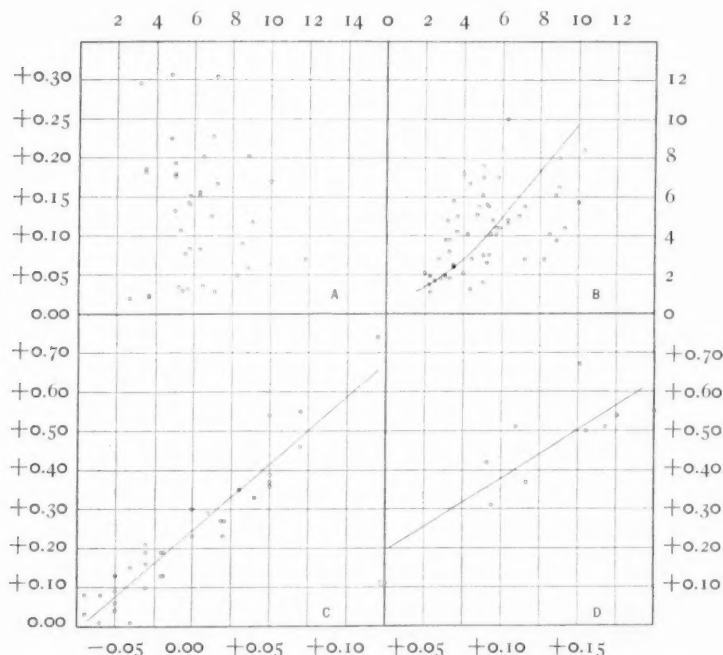


FIG. 1.—(A) Abscissae: estimates by Plaskett and Pearce of the intensities of the interstellar calcium line K for stars in the Cepheus region. Ordinates: color excesses by Elvey and Mehlin. (B) Comparison of estimates of K intensities by Plaskett and Pearce (abscissae) with those by Struve (ordinates). (C) Abscissae: color excesses determined by Bottlinger. Ordinates: by Elvey. (D) Abscissae: color excesses determined by Elvey and Mehlin. Ordinates: by Elvey.

For the combination of observations by Elvey and by Bottlinger, the relation

$$y = 3.41x + 0.246$$

was derived (see Fig. 1, C). The Pearson coefficient of correlation for this scatter diagram is 95 per cent  $\pm 1$ .

The conversion of the color excesses of stars in the Cepheus region

<sup>9</sup> *Veröffentlichungen der Universitätssternwarte zu Berlin-Babelsberg*, 3, Heft 4, 21, 1933.

<sup>10</sup> *Op. cit.*, 74, 298, 1931.

(obtained by Elvey and Mehlin) to the scale adopted was effected by the equation of the straight line in Figure 1, *D*,

$$y = 2.46x + 0.134.$$

The Pearson coefficient of correlation is 85 per cent.

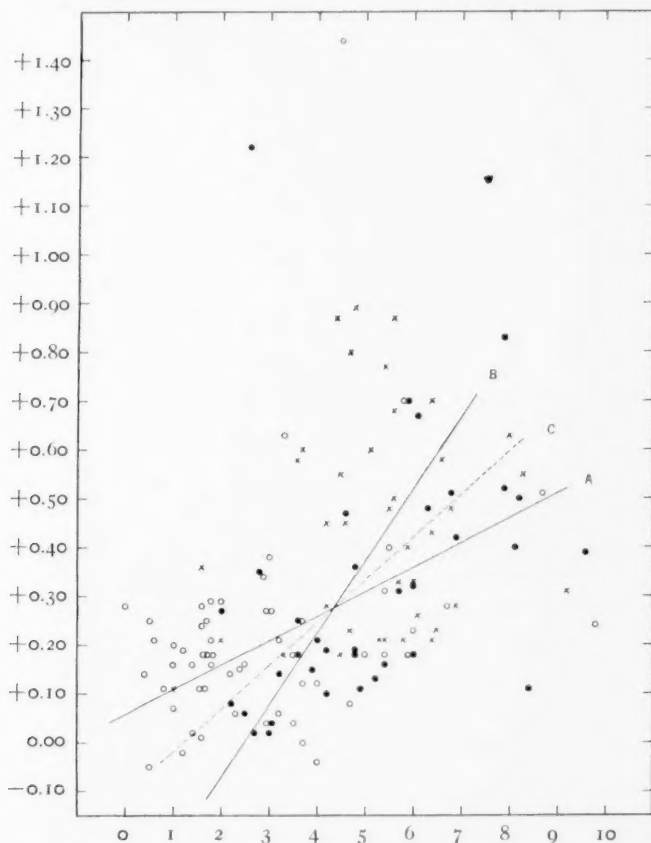


FIG. 2.—Ordinates: color excesses. Abscissae: intensities of interstellar K. Open circles are single weighted and dots are double weighted (average of two estimates of K). Crosses represent observations in Cepheus region. *A* is regression line of color excess on intensity. *B* is regression line of intensity on excess. *C* is bisector of vertical angle formed by *A* and *B*.

2. I am indebted to Dr. Struve for the use of his estimates of the intensity of the interstellar calcium line K for almost every star here considered. These intensities have not been published individually.

The scale of the estimates of Plaskett and Pearce<sup>11</sup> was arbitrarily adopted. Figure 1, *B*, illustrates the scatter found in comparing observations of sixty-five stars common to both systems. The curve, which was drawn in free-hand, was used to reduce Struve's intensities to the scale of Plaskett and Pearce. In the cases in which a star had estimates from both sources, the converted Struve estimate and the Plaskett and Pearce estimate were averaged.

3. Since the color excesses in the Cepheus region have already<sup>8</sup> been compared with estimates of interstellar calcium by Struve, another such comparison was made with the now available Plaskett and Pearce estimates. The lack of correlation found before is here confirmed, as illustrated in Figure 1, *A*.

4. Figure 2 contains all the data arranged in comparable form. The solid dots are double weighted, that is, there were for these stars two estimates of the intensity of the interstellar calcium line. The stars of the Cepheus region (also double weighted) are represented as crosses. Although they in themselves show no correlation with the intensity of K, they appear to fit into the general diagram fairly well.

The regression line of intensity on color excess (*B*), the regression line of excess on intensity (*A*), and the bisector of these two vertical lines (*C*) have been drawn in. The Pearson coefficient of correlation is, as was expected, low,  $55 \pm 4$  per cent; the mean square error of estimate of color excess was determined as 0.15 and that of intensity as 1.9. The test for linearity of regression is satisfied. These statistics were determined without the use of the Cepheus points.

5. From the relation  $\bar{r}A = 4.4(I - 1.51)$  found by Plaskett and Pearce,<sup>11</sup> and the value of  $A = 0.017$  kilometers per parsec, the intensities of K were evaluated as mean distances. With the interpretation that the correlation of color excess with the intensity of the interstellar K line is an effect of distance, the reddening in space may be estimated to be about 0.34 mag. per 1000 parsecs on the scale used.

CHRISTINE WESTGATE

YERKES OBSERVATORY  
April 1933

<sup>11</sup> *Publications of the Dominion Astrophysical Observatory*, 5, No. 3, 1932.

## REVIEWS

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*Kinetics of Homogeneous Gas Reactions.* By LOUIS S. KASSEL.  
("American Chemical Society Monograph Series," No. 57.) Pp.  
330. Figs. 25. New York: Chemical Catalog Co., Inc., 1932. \$6.50.

The author emphasizes the rôle of kinetics by beginning the book with the statement that the entire field of chemistry may be divided into two parts: thermodynamics and kinetics. The former branch stipulates the chemical changes that are permitted under a given set of conditions; the latter describes—rather, postulates or assumes—what processes will actually occur. The conclusions of thermodynamics are independent of any particular mechanism and remain unchanged. Such a condition allowed for the authoritative treatment given the subject first by Gibbs and finally in its more applicable form by G. N. Lewis. In many branches of this field the final word has been said. Kinetics, on the other hand, does not allow any such final word. Since it leans so heavily on hypothesis, the subject may always be in a state of development. One might say that Kassel's book is the first good work in this field. Without question, it is the best work on this subject that has yet been published.

The scientist very often describes his observations entirely in terms of theory. The swing of a galvanometer may be overlooked and in its place one sees an interatomic or subatomic phenomenon. In no field is this tendency more prominent than in the field of kinetics. Theory and experimental fact are very loosely connected and often confused. Aware of this weakness on the part of some, the author has been persistent throughout in his effort to discriminate between theory and observation. The text falls into two main divisions. The first half deals with theory, and here unimolecular, bimolecular, and trimolecular reactions are treated. The second half emphasizes experiment, interpreted, of course, in the light of the theory previously presented. Here the author considers first-order, second-order, and third-order reactions (differentiated from the terms "unimolecular," "bimolecular," and "trimolecular").

After an introductory chapter on "Elementary Reactions" the author begins the theoretical treatment with a "Statistical-Mechanical Interlude," a necessary introduction since the author consistently uses statistical mechanics in developing the subject. In the third chapter, "Bimolec-

ular Reactions," the quantum-mechanical deductions of London and Eyring and Polanyi are given. These developments are perhaps the most ephemeral of any in the book. The rest of this section is given over to the statistical-mechanical treatment.

Practically all the known simple elementary reactions studied thus far are included in the first three chapters of the experimental section, while under "Complex Reactions" only enough of these reactions are described for adequacy in illustration. Whenever necessary the experimental values have been recalculated and put into a unified form.

In both the experimental and the theoretical sections a critical attitude has been maintained. Often this may be detrimental to a good presentation, but in this case we may put faith in the author's good judgment.

The book will find use both as a reference book and as a text for advanced work. It seems unfortunate that its use as a text will undoubtedly be restricted by the high price that the publishers deem necessary for a book of this kind.

T. R. HOGNESS

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*Kosmos.* By WILLEM DE SITTER. Cambridge, Mass.: Harvard University Press, 1932. Pp. 138. Bound, \$1.75.

This book consists of six chapters whose substance is that of the six Lowell lectures delivered by the author in Boston in 1931. The author states in the Preface that the lectures were not intended to be a complete history of the structure of the universe. That the work is not a complete history is shown by the omission of a discussion of the work of such outstanding figures as Seeliger, Huggins, and Schwarzschild. A few epochs and persons were chosen for full treatment and the result is an excellent series of sketches of certain important figures and periods. The first lecture, after an introductory section on the aims and methods of scientific research, covers the periods of the Greeks and of Ptolemy. Chapter ii outlines the birth of modern astronomy as shown in the work of Kepler, Galileo, and Newton, together with a short discussion of the seventeenth-century astronomers other than Newton. The principal part of chapter iii is taken up with William Herschel. Shorter discussions are given of John Herschel and Wilhelm Struve. A very complete outline is given of the work of Kapteyn in chapter iv. Chapter v gives a summary of the present state of our knowledge of the galactic and extra-galactic systems, and chapter vi an excellent popular discussion of relativity and modern theories of the universe.

This book should be popular both with astronomers and other scientists and also with laymen. It is written, on the whole, very clearly, and avoids complicated technical terms as much as possible. The author has done especially well in his treatment of Kapteyn and of modern theories of the universe.

W. W. MORGAN

*Trattato di Astronomia Siderale*, Vol. II: *Le Stelle*. By GIUSEPPE ARMELLINI. Bologna: Nicola Zanichelli, 1931. 8vo. Pp. viii+559; 142 diagrams and photographs. Bound, L. 100.

The first volume of Armellini's *Astronomia Siderale*—reviewed in the *Astrophysical Journal*, 69, 243, 1929—contained the “Parte generale” of the treatise, viz., Part I, “Uranografia,” and Part II, “Uranometria.” The second volume, now under review, contains the third, fourth, and fifth parts of this elementary college course; the subjects covered are stars in general, variable stars, and binary and multiple stars. The third and last volume will deal with the distribution and motions of the stars in space, with star clusters, and with nebulae.

The volume under review is probably the only up-to-date and reliable Italian manual of astrophysics; as such it is a welcome addition to the Italian astronomical literature; it is based on the course offered by the director of the astronomical observatory to his students at the University of Rome; it presupposes a rather limited acquaintance with higher mathematics and very little knowledge of modern physics; it offers a clear and orderly exposition of the problems and methods of astrophysics chosen by the author. It would not be fair to compare this one-man *Trattato* with such co-operative works as the *Handbuch der Astrophysik*, or with the *Physik des Kosmos* volume of Müller-Pouillet's *Lehrbuch*, or with Russell-Dugan-Stewart's *Astronomy*; it could be compared more justly with Kasimir Graff's *Grundriss der Astrophysik* or with Jean Bosler's *Astrophysique*.

The first part of the present volume devotes about two hundred and twenty pages to the following subjects: spectral types; luminosity, diameters, mass, and density; stellar atmospheres; sources of stellar energy, and transformation of matter into energy; internal constitution of the stars; and evolution of the stars. The variable stars are treated, in about one hundred and sixty pages, under the following chapter headings: “Generalities”; “Construction and Discussion of Light Curves”; “Novae or Temporary Stars”; “Irregular Variables”; “Long-Period or Semi-regular Variables”; and “Regular Variables or Cepheids.” The last part of the

volume deals, in about one hundred and forty pages, with visual, spectroscopic, and photometric binary systems. An Appendix contains, in a score of pages, a short list of "recommended" variables, and tables of orbital elements of visual, spectroscopic, and eclipsing binaries. There is no subject or name Index.

The illustrations are well chosen; the diagrams are generally well reproduced; this cannot be said of the photographs, especially if one takes into consideration the good quality of the paper. The very numerous bibliographical references are an important and welcome feature of the volume under review; it is to be regretted that they were not checked, standardized, and proofread with more care. Most of the long mathematical footnotes are irrelevant and could be shortened or even omitted.

A. POGO

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*Tafeln für die Differenzenrechnung sowie für die Hyperbel-, Besselschen, elliptischen und anderen Funktionen.* By KEIICHI HAYASHI. Berlin: Julius Springer 1933. Pp. 66. RM. 12.

In the preparation of various numerical tables, of which the author has published several in the past, he has established a number of auxiliary tables which are useful for independent checking and extending by interpolation. We find here very extensive tables for the direct computation of successive orders of differences up to the twelfth and for interpolating by increments as small as one-hundredth of the original step. To the numerical parts are added the higher-order differential coefficients of a number of algebraic expressions.

We find next an extension of the tables of numerical values of exponential, hyperbolic, Bessel, and elliptic functions covering larger ranges of arguments or interpolated to smaller steps than the previously published tables. Tables of the eleventh and twelfth powers of whole numbers up to 100 and of the fourth and fifth powers up to 1000 are added. The latter fill in the blanks left around the partial tables in the second half of the book and are therefore scattered over a large number of pages.

G. VAN BIESBROECK